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Low-Flow Aquatic Habitat Restoration Evaluation, the RCHARC Methodology, Goose Creek, Colorado

by C. Bradley Florentin, Steven R. Abt,
Chester C. Watson, Kent L. Collins,
Colorado State University

J. Craig Fischenich, John M. Nestler, WES

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by C. Bradley Florentin, Steven R. Abt,
Chester C. Watson, Kent L. Collins

Department of Civil Engineering
Colorado State University
Fort Collins, CO 80523

J. Craig Fischenich, John M. Nestler

U.S. Army Corps of Engineers
Waterways Experiment Station
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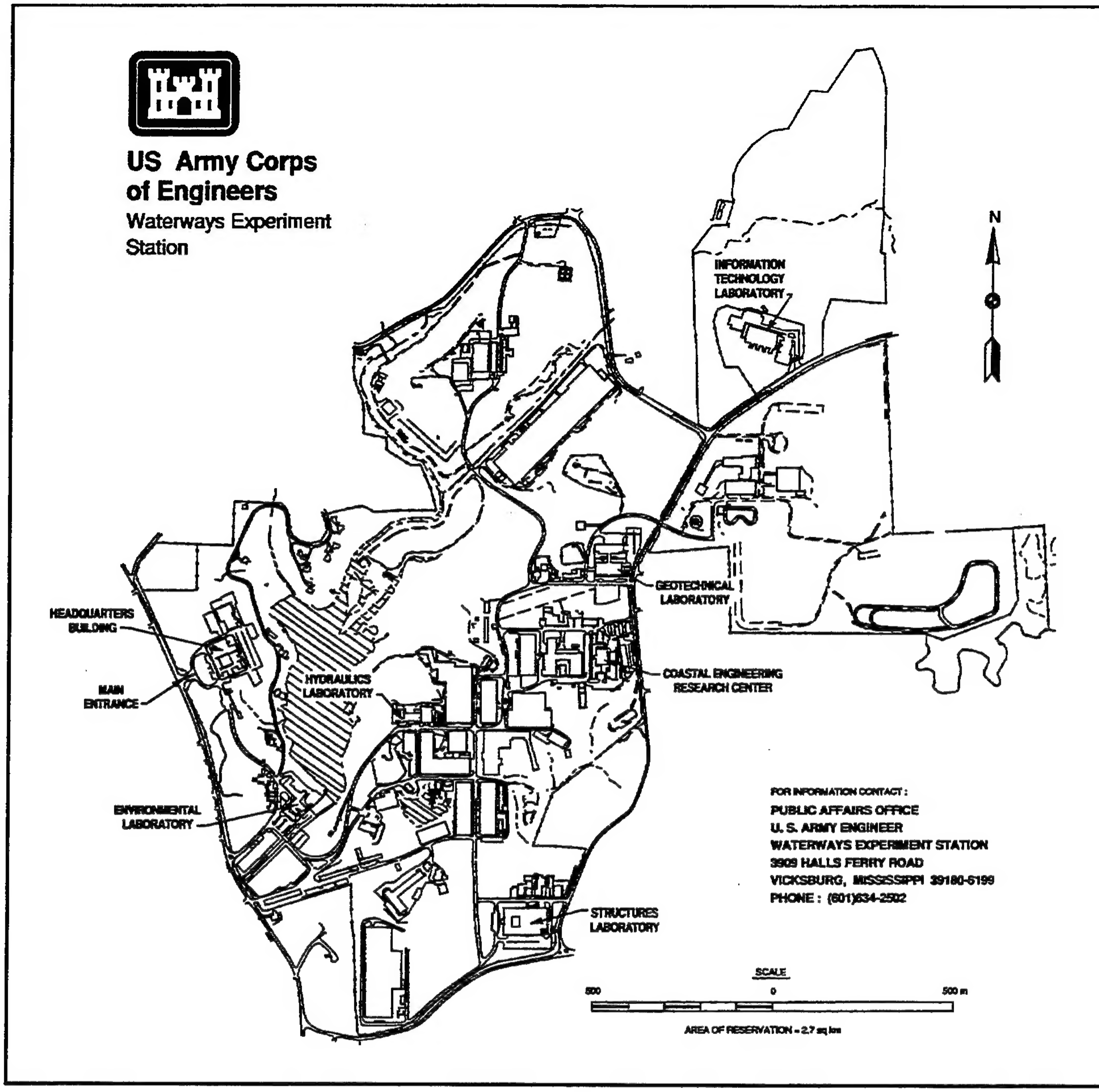

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Low-Flow Aquatic Habitat Restoration Evaluation, the RCHARC Methodology, Goose Creek, Colorado (TR EL-97-1)

ISSUE: Dams and local flood control works alter aquatic habitat conditions in tailwaters and streams. The adverse impacts of these activities can be avoided or mitigated provided the impacts can be quantified. No widely accepted methods exist to incrementally relate instream aquatic habitat, channel modification, and flows to allow trade-off analyses between cost, design, and habitat benefits.

RESEARCH OBJECTIVE: The principal objectives of this research work unit were to (a) formulate a method that permits the incremental evaluation of instream aquatic habitat, channel modification, and flow; (b) evaluate the methodology through application to several stream systems; and (c) develop a computer code and guidelines for the application of the methodology.

SUMMARY: The Riverine Community Habitat Assessment and Restoration Concept (RCHARC) was developed by the U.S. Army Engineer Waterways Experiment Station (WES) to compare the aquatic habitat characteristics of two or more study reaches. RCHARC offers three distinct advantages over other aquatic habitat assessment methods: (a) it implicitly uses an ecosystem or community approach to assess habitat quality rather than a species-based approach; (b) it presents requisite channel conditions in terms the design engineer understands (i.e., cumulative distribution of depth and velocity); and (c) it relieves the investigator of the tedious and ambiguous task of developing lifestage-specific suitability curves for each species.

The Beta version of RCHARC, developed to evaluate long-term habitat impacts on the Missouri River, was evaluated for use on small, coldwater systems in 1994 and was reported in WES TR EL-96-8, "Low-Flow Habitat Rehabilitation-Evaluation, RCHARD Methodology, Rapid Creek, South Dakota." The RCHARC was modified on the basis of findings of that investigation, and the revised RCHARC was further evaluated by applying it to three reaches of Goose Creek, Colorado. This report presents the findings of the evaluation. A summary of the RCHARC procedure is also presented.

AVAILABILITY: The report is available on Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199; telephone (601) 634-2355. To purchase a copy, call the National Technical Information Service (NTIS) at (703) 487-4650. For help in identifying a title for sale, call (703) 487-4780. NTIS numbers may also be requested from the WES librarians.

About the Authors: The report was written by Mr. C. Bradley Florentin, Dr. Steven R. Abt, Mr. Chester C. Watson, and Mr. Kent L. Collins, Colorado State University, and Drs. J. Craig Fischenich and John M. Nestler, WES. **Point of contact** is Dr. Fischenich, WES, telephone (601) 634-3449.

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Preface

This report was prepared by the Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), and Colorado State University as part of the Environmental Impact Research Program (EIRP). The research reported herein was conducted as part of Work Unit 32698 entitled "Assessing Benefits of Channel Modification for Aquatic Habitat in Tailwaters and Local Flood Control Channels." Funding was provided by Appropriation No. 96X3121, General Investigation. The EIRP is sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to WES under the purview of EL. Program monitors were Ms. Cheryl Smith, Mr. Forester Einarsen, and Mr. Frederick B. Juhle, HQUSACE. Dr. Russell F. Theriot, EL, was EIRP Program Manager.

The report was prepared by Mr. C. Bradley Florentin, Dr. Steven R. Abt, Mr. Chester C. Watson, and Mr. Kent L. Collins, Colorado State University; Dr. J. Craig Fischenich, Environmental Engineering Division (EED), EL; and Dr. John M. Nestler, Water Quality and Contaminant Modeling Branch (WQMCB), Environmental Processes and Effects Division (EPED), EL.

The study was performed under the direct supervision of Mr. Norman R. Francingues, Chief, EED; and Dr. John W. Keeley, Director, EL. Dr. Nestler was the project Principal Investigator. Ms. D. H. Tillman and Ms. L. T. Schneider, both of WQMCB, provided in-house technical review.

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1 Introduction

Traditionally, river channels have been modified with consideration to human lives and property. Rivers have been channelized to reduce meandering and increase flood capacity. These modifications to the rivers often come at the expense of the existing aquatic community. Recently, consideration has been given to the environment, recreation, and aesthetic aspects in the channel restoration process.

The environmental awareness has enhanced the value of aquatic communities in the river ecosystem. Techniques are being developed to estimate the impact of river restoration and/or rehabilitation on the aquatic habitat. These approaches may be used as a design tool to assist a design team in evaluating proposed channel modifications prior to construction.

Nestler, Schneider, and Latka (1993) developed the Riverine Community Habitat Assessment and Restoration Concept (RCHARC) at the U.S. Army Engineer Waterways Experiment Station to compare aquatic habitats in the main stem reservoir tailwaters of the Missouri River. RCHARC is a simulation approach for relating the effects of flow alterations on aquatic biota using the stream system as a basis of comparison, which is a "comparison standard" for the analysis against which the project alternatives can be evaluated (Abt et al. 1995).

The goals of this study were to evaluate the accuracy and efficiency of the RCHARC process and propose modifications to the RCHARC procedure based upon the findings of a field evaluation. Specific objectives formulated to assist in the attainment of these project goals include the following:

a. Select a stream for study that exhibits (a) natural, restored, and degraded reaches; (b) reaches that are classified as gold medal trout fishing areas by the Colorado Division of Wildlife; and (c) access to the selected reaches.

b. Select and delineate three reaches for evaluation that can be respectively classified as natural, restored, and degraded.

c. Collect data necessary for the application of RCHARC to each of the three selected reaches.

d. Execute an RCHARC analysis using the field-collected data to compare the similarity between the three reaches.

e. Recommend modifications to the procedure/program.

f. Evaluate the recommended modifications by comparing the RCHARC program results with those obtained from a modified RCHARC program.

2 Background

A review of channel restoration, design, modeling, and assessment was performed as background to this study. The review focused on microhabitat definitions, case studies of channel restoration efforts, numerical modeling techniques used for restoration, RCHARC methodology, usage of the Canberra metric coefficient, and bed material collection and assessment techniques.

Microhabitat Definitions

Stream channel restoration is presently qualitative in nature, as few standards or criteria relating to aquatic habitats are universally accepted by restoration proponents. Part of the reason for this is that the complex situation between the physical, chemical, biological, and sociological character of aquatic ecosystems is not well understood. Restoration of aquatic habitats is further complicated in that it is difficult for engineers, biologists, and environmentalists to effectively communicate because each profession possesses a unique focus and vocabulary in describing the same stream. Therefore, the complex biological habitats must be segmented into easily definable categories: aquatic biota are routinely categorized into macrohabitat and microhabitat.

Macrohabitats for aquatic biota include water and air temperature, water quality, geology, elevation, bed slope, and water supply (Bovee 1982). These components of habitat apply to an indefinite stream reach length and provide the template on which the stream's fauna and flora thrive given favorable microhabitat conditions. Microhabitat components of aquatic habitat include velocity, depth, substrate, and cover (Amour, Fisher, and Terrell 1984). Fish and other aquatic organisms respond to and flourish in microhabitats that are located within favorable macrohabitats (Bovee 1982).

Microhabitats are directly related to the stream hydraulic conditions of channel structure. Channel structure describes the cover and substrate related to the physical characteristics of the channel. Substrate is more influenced by hydraulic parameters than cover, and this relationship is described by the variable Q_{17}, which represents the discharge that is exceeded 17 percent of the

time (Prewitt and Carlson 1977). The Q_{17} variable is important to microhabitat in that it is the amount of flow that flushes impacted fine sediment out of the substrate (Bovee 1982).

Hydraulic parameters important to microhabitat include depth and velocity. Both are directly related to discharge, but in a fashion that is both spatially and temporarily variable. In using RCHARC, it is assumed that for a specific discharge, there exists a distribution of flow depths and velocities. These distributions represent the habitat template upon which the aquatic community is structured. Changes in the frequency distribution of the flow depth and velocity will result in associated changes in the aquatic community. Depiction of a stream reach in terms of frequency distributions of depth and velocity is likely to capture heterogeneity that dictates the aquatic community composition (Abt et al. 1995). A diagram representing the habitat classification system is presented in Figure 1.

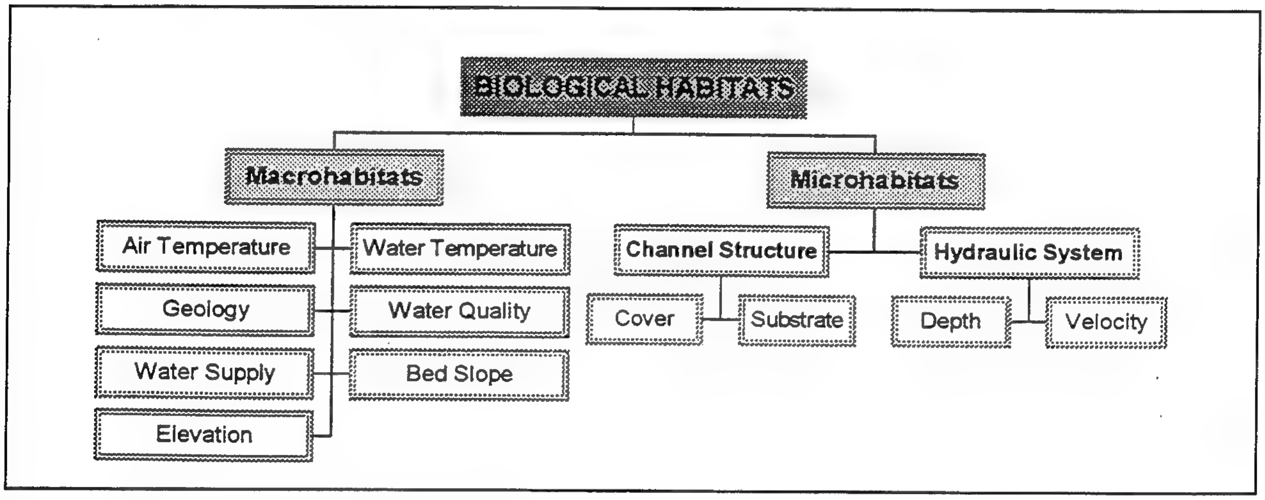

Figure 1. Biological habitat categories

Channel Restoration Efforts

Channel rehabilitation and restoration have become important elements in stream channelization. It is essential to consider the design aspects of successful restoration projects through examination of case studies. Frissell and Nawa (1992) indicate that poor engineering design and lack of consideration of the overall physical processes occurring in the stream are major contributors to unsuccessful projects. Restoration of stream habitat is also costly. The total cost of the Rapid Creek restoration project in Rapid City, SD, was approximately $526,000 (Glover and Ford 1990). It is evident that due to the expense of a habitat restoration project, a comprehensive consideration of the design aspects is required by the design team to ensure success. A typical design team is composed of, but not limited to, engineers, biological scientists, landscape architects, and citizen groups. Despite the need for technical

criteria for restoring stream channels, there is a lack of universally accepted, quantitative design standards and criteria addressing the restoration of aquatic habitat.

Selected restoration guidelines

In the design state, the design team must determine the extent of the habitat to be restored. A complete biological habitat restoration requires the reestablishment of historic inflow characteristics (Toth 1993). However, other project objectives and/or requirements may not allow historic inflow characteristics to continue or exist. An example would include a dammed river that provides hydropower. A return to complete historic flows would render the hydropower plant useless. An alternative is to improve the microhabitat components contributing to the restoration of aquatic habitat. Improving aquatic habitat can indirectly lead to improvement of the littoral vegetation and wildlife habitats (Burgess 1985). Many habitat restoration designs include structural modification. It has been found, however, that these modifications are inappropriate for three conditions: streams that exhibit high sediment loads; streams that have high peak flows; or streams that contain highly erodible banks (Frissell and Nawa 1992).

Kissimmee River

Before 1962, the Kissimmee River flowed naturally and unimpeded from Lake Kissimmee to Lake Okeechobee in Florida. The river and its floodplain was a haven to 39 species of fish, 19 species of waterfowl, and diverse littoral flora (Toth 1993). The Kissimmee River was subsequently channelized between 1962 and 1970. Six water control structures were built during this same period. As a result, many of the adjacent marshes and sloughs were drained, and the channel was narrowed and deepened. This significantly reduced the habitat for the wading birds and waterfowl. The reduced diversity in the river channel and the impounded water reduced the dissolved oxygen to a toxic level of 2 mg/L and below (Toth 1993).

It was evident that habitat restoration was required. Results from studies conducted during the early 1970s provided documentation for the Florida legislature to enact the Kissimmee River Restoration Act in 1976. A Partial Backfill Alternative was then adopted from the results of an Army Corps of Engineers environmental impact statement (U.S. Army Corps of Engineers 1985). As part of the restoration alternative, it was determined that the stage and discharge characteristics be reestablished as well as the creation of a flow-through marsh. As a result, portions of the waterfowl habitat returned. However, dissolved oxygen levels did not recover except in one remnant river channel. The remnant river channel had been reopened and received regular baseflows.

The project team determined that it was feasible to restore the habitat of the Kissimmee River (Toth 1993). The inflow characteristics were not, in this case, able to be fully reestablished; therefore, the habitat was not fully restored. Toth (1993) provided some recommendations for a restoration evaluation program. The recommendations include the following:

a. Provide a thorough understanding of ecosystem structure and function, including predictive capability for most components—with and without restoration.

b. Show direct cause-effect relationships between restoration measures and ecological responses.

c. Include quantifiable biological responses and statistical comparisons.

d. Document ecological changes that are of both social and scientific importance.

Low-flow channels

Abt et al. (1994) presents findings on site visits to five streams that were successfully restored. The five streams visited were Rapid Creek in Rapid City, SD; the Blue River in Breckenridge, CO; the South Platte River near Chatfield Reservoir in Denver, CO; the Wildcat Creek in Richmond, CA; and the San Pablo Creek in Richmond, CA. The streams were restored to enhance flood storage, reclamation of extensive mining efforts, recovery from channelization, and recovery from sedimentation damage.

Four findings were extracted from these site visits. The first indicator of a successful restoration project was a team approach which was characterized by the cooperation of scientists, engineers, landscape architects, and citizen groups. Another commonality was the lack of design criteria for aquatic habitats. Although habitat restoration concepts are transferable, the transfer is difficult while still maintaining a high degree of success. Third, low-flow channel design criteria were used. The design criteria for a low-flow channel are presented in Table 1 (Fischenich et al. 1993). Fourth, it was recommended that the design restoration team identify alternatives to take advantage of the multipurpose nature of many of the habitat enhancement structures.

Incised stream restoration

Aquatic habitat restoration has met with success in warmwater incised streams. Shields, Knight, and Cooper (1995) outline the success of small stone weirs and Shields, Cooper, and Knight (1995) describe favorable effects of extending spur dikes in enhancing aquatic habitat. Three streams were selected for observation for the stone weir study. One stream was incised, one was incised and weirs placed at specified locations, and one stream was

Table 1
Low-Flow Channel Design Criteria

Design Parameter	Recommended Criteria
Low-flow design flow	1- to 2-year recurrence
Minimum flow depth	0.3 m
Bend radius	3 times channel width for small streams
Meander	1.1 < sinuosity < 1.5, or match adjacent reaches
Randomly placed rocks	Not effective in fine-grained streams, placed where velocity > than 1 m/s, one rock per 28 sq m of channel, 0.6 m min. diameter, no greater than 0.2 channel width
Pools	Pool-to-pool interval of five to seven widths, place in bends, pools no longer than three channel widths, no shorter than one channel width, place on alternating sides
Riffles	Place in straight reaches, riffle length: 1/2 to 2/3 pool length, riffle width 10 percent to 15 percent wider than pool, alternate pools and riffles
Deflector wing	Place on max 3-percent channel slope, five to seven channel widths apart, anchor more than 1.2 m into bank, height: 0.15 to 0.30 m above low-flow water surface, install on alternate banks, extend into low-flow channel 0.25 to 0.33 channel width, bank protection may be needed on opposite bank
Sill	Height of 1/3 design discharge flow depth, keyed into bed minimum of twice height, bank protection needed one to three channel widths downstream
Dike	Length less than 15 percent to 25 percent channel width, space of 3 to 6 times dike length, orient 90 to 150 deg, height: 0.15 to 0.3 m above low-flow water surface
Bank cover	Cover placed at low-flow water surface, place on outer bank, depth greater than 1 m
Microorganisms	Recommended velocities of 0.3 to 0.8 m/s
Food production	Recommended velocities of 0.5 to 1.1 m/s

nonincised. The goal was to restore the incised channel to exhibit the aquatic habitat characteristics shown by the nonincised channel. Stone weirs were selected to provide pool habitat in the incised channel. It has been shown that scour holes resulting from such structures in unstable, incised channels tend to support more species and larger fish than the surrounding channel habitat without structures (Winger et al. 1976; Shields and Hoover 1991; Knight and Cooper 1991; Shields, Knight, and Cooper 1995). One year after restoration, the mean width, depth, and velocity exhibited changes of +56, +150, and -56 percent, respectively (Shields, Knight, and Cooper 1995). Although there was not a drastic change in community structure, the restored stream became similar to the nonincised channel rather than the reference incised channel. This study is ongoing as data continue to be collected and analyzed.

A similar study was performed by Shields, Cooper, and Knight (1995) and involved extending existing spur dikes to restore pool habitat in an incised stream. The project met with immediate success. Only 4 months after restoration, the scour holes caused by the spur dike extensions had increased from about 32 to 84 cm. It was also determined that a dike extension angled downstream produced deeper scour holes than an extension angled upstream. The number and size of fish were reported to increase by 50 percent. The extension of the spur dikes had little effect on the bed material size in the main channel.

Structures that enhance aquatic habitat

A brief discussion of aquatic habitat enhancing structures extracted from the *Ohio Rainwater Handbook* (Ohio Department of Natural Resources 1995) is noteworthy. The six structures and channel configurations presented include eddy rocks, deflectors, grade stabilization dams, gravel riffles, streambank stabilization, and two stage channels. Eddy rocks are used to reduce velocity, provide protective cover, and provide scour holes downstream of the eddy rocks for aquatic habitat. Deflectors, or hard points, can be used to stabilize eroding banks by creating slower velocities near the bank. Deflectors also direct the flow away from the bank and, if used on alternating sides of the channel, can promote meandering. Grade stabilization dams, or instream checks, are used to decrease the slop of a channel which, in turn, reduces stream velocities. Grade stabilization dams also increase the depth of scour holes and oxygen content. To prevent reduced aquatic habitat value, it is recommended that the dams not create backwater pools (Ohio Department of Natural Resources 1995).

Another channel enhancement feature described by the handbook includes gravel riffles which enhance and promote stable substrate in erosive streambeds. The streambank stabilization technique recommended by the *Ohio Rainwater Handbook* is vegetation. Vegetation provides bank protection and allows a thick network of roots to continue to protect the bank with little or no maintenance. Two stage channels are used to provide aquatic habitat during low flows (less than 2-year events) while providing hydraulic efficiency during flood flows (2- to 10-year events). The handbook provides construction specifications as well as recommendations as to when to use a particular habitat structure.

PHABSIM Habitat Evaluation Model

PHABSIM is a habitat evaluation program based on suitability index curves and is life stage specific (Milhous, Updike, and Schneider 1989). There are three steps in the evaluation of habitat in PHABSIM. The PHABSIM program simulates (a) the water surface elevation, (b) the flow velocity through the channel, and (c) the physical habitat. PHABSIM bases its physical habitat

evaluation on the Weighted Usable Area (WUA), which is calculated using Equation 1 (Milhous, Updike, and Schneider 1989).

$$WUA = \int_A f(v,d,ci)\,dA \tag{1}$$

where

v = velocity

d = depth

ci = channel index (based on cover and substrate)

The disadvantage of using Equation 1 is that the ci is subjective and difficult to determine.

A subprogram of PHABSIM is IFG4. The IFG4 subprogram calculates simulated velocities for a cross section given calibration velocities, discharge, cross-section geometry, and water surface elevation. IFG4 must use field-collected velocities to calibrate its synthesis of simulated velocities. When only one velocity data set is available to calibrate the model, the program defaults to Equation 2, derived from the Manning's Equation (Milhous, Updike, and Schneider 1989).

$$v(k) = \frac{[a(k) * r(k)^{0.667}]/n(k)}{\sum_{j=1}^{nc} [a(j) * r(j)^{0.667}]/n(j)} * QS \tag{2}$$

where

$v(k)$ = unknown velocity of a cell

$a(k)$ = area of a cell of unknown velocity

$r(k)$ = hydraulic radius of cell of unknown velocity

$n(k)$ = Manning's roughness of cell of unknown velocity

$a(j)$ = area of cell of known velocity

$r(j)$ = hydraulic radius of cell of known velocity

$n(j)$ = Manning's roughness of cell of known velocity

nc = total number of wet cells

QS = streamflow for which velocity is to be calculated

IFG4 is also capable of calibration with multiple velocity sets. When using multiple velocity sets, the constants a and b in Equation 3 (Milhous, Updike, and Schneider 1989) are solved and may be used in simulation or specific discharges.

$$v_i = a_i * Q^{bi} \tag{3}$$

where

v_i = velocity to be calculated

a_i = constant 1

Q = streamflow for which velocity is to be calculated

b_i = constant 2

After entering the input data into IFG4, the subprogram is initiated. The velocities are simulated by the IFG4 subprogram and compiled into an output data set. These generated data sets are converted from binary to ASCII using the LSTVDX subprogram included in the PHABSIM program package. The ASCII data sets include simulated depths and velocities.

The PHABSIM methodology has received considerable criticism for applications on large warmwater river systems (Bain and Boltz 1989; Nestler, Schneider, and Latka 1993). It is necessary to develop suitability curves for four life stages pertaining to each species of fish that exist in the stream when applying PHABSIM. It becomes difficult to determine and provide the flow requirements for aquatic habitat in river systems where many species of fish exist. It is also difficult to produce defensible suitability curves when there are major alterations in channel morphology and flow regime. Suitability curves for impacted species in highly modified systems are suspect because the system could be deficient in one or more critical habitat components (Tyus 1992). However, it has been shown that fish do respond to depth and velocity patterns (Bain, Reed, and Scheidegger 1991).

Introduction of RCHARC

Another habitat evaluation model developed to assist in the design of a stream restoration or rehabilitation project is the RCHARC. RCHARC was developed by Nestler, Schneider, and Latka (1993) to analyze the effects of river and tailwater operations on the physical environments of native riverine

habitat. RCHARC was designed to overcome shortcomings experienced in the PHABSIM methodology discussed above.

The RCHARC program is a series of subprograms written in SAS, a computer program for statistical computations. Fischenich et al. (1993) point out that the PHABSIM process does not include the effects of competition, predation, or interspecies interactions. RCHARC is not life stage specific. The RCHARC incorporates many of PHABSIM's shortcomings by making them implicit in its methodology. Therefore, the RCHARC process provides a comprehensive yet simplified analysis compared with the PHABSIM process.

The RCHARC process is comprised of two programs. The first program sorts and regroups the data sets according to discharge, depth, and velocity, respectfully. The second program segments the depth-velocity pairs into classified mesohabitats shown in Figure 2 (Aadland 1993). RCHARC was then enhanced (a) to produce a two-dimensional topo-plot of velocity versus

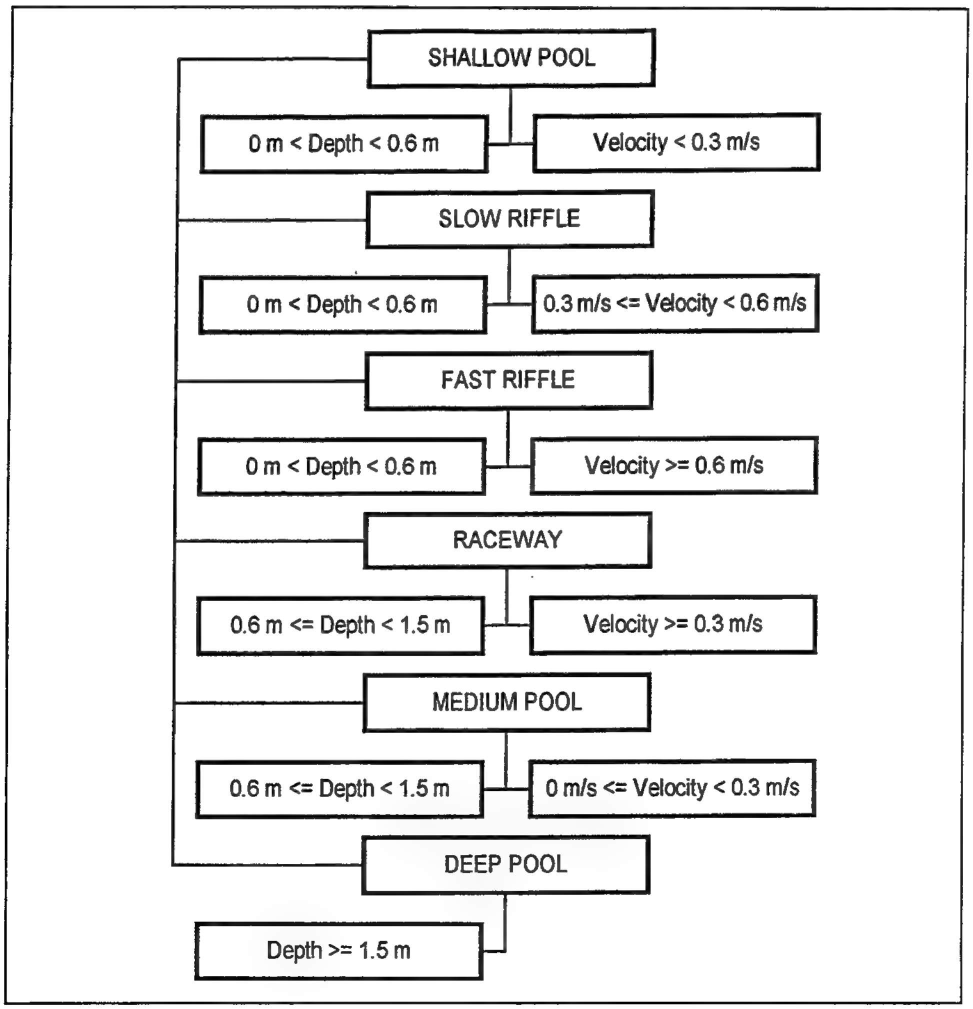

Figure 2. Mesohabitat classifications (Mesohabitats as described by Aadland (1993))

depth and plotting lines of equal percent occurrence and (b) to compute a coefficient of dissimilarity. The process allows a quantitative and qualitative analysis of the degree of similarity between a natural reach (control standard river system, CSRS) and a restored reach. The quantitative analysis is performed by comparing the percent of the total habitat in each perspective habitat category and the computed dissimilarity coefficient. The qualitative analysis is performed by comparing the two-dimensional topo-plots of the CSRS and the restored reach.

The RCHARC methodology requires the design team to select a comparison standard river system (CSRS) which represents the ideal or target macrohabitat and microhabitat conditions in terms of channel structure and the hydraulic system characteristics of depth and velocity for a target population. The CSRS is selected based on professional consensus, physical similarity to the project system, and/or similarity of the aquatic community (Peters et al. 1996; Peters 1994; Nestler, Schneider, and Latka 1993).

The CSRS can be a nearby river system, reaches of the river further upstream or downstream of the project and not impacted by the project, or the project river reach but evaluated in a without-project condition (Nestler, Schneider, and Latka 1993).

The RCHARC compares the hydraulic characteristic similarity between the CSRS and the restored reach of the river. Valid comparisons can be achieved only by selecting a CSRS that has similar macrohabitat characteristics as the restored reach. To achieve similarity, only the microhabitat components of the reaches will need adjusting. An explanation of the RCHARC procedure follows.

Previous evaluation of the RCHARC process

Peters (1994) and Peters et al. (1996) reviewed the original RCHARC process as well as other habitat evaluation models. It was recommended that HEC-2 be used in conjunction with the RCHARC model. The advantages and disadvantages as well as recommendations for the RCHARC model improvement were presented. Advantages of the RCHARC process included the following (Peters 1994; Peters et al. 1996):

- The RCHARC output may be used to compare hydraulic (velocity and depth) conditions and habitat similarity between proposed channel reaches.

- Similar hydraulic parameters at specified discharges indicate similar habitat and should also lead to similar sediment transport capacities.

- When depth and velocity frequency distributions are dissimilar between comparison reach conditions, habitat enhancement features, including dikes, boulders, pools, riffles, drops, etc., may be considered.

Alternative designs may be introduced and assessed using RCHARC. This process is repeated until a design is achieved which meets both habitat and flood conveyance objectives.

- The combined RCHARC/HEC-2 channel assessment procedure requires a team approach to evaluating the comparison reaches. Biologists, landscape architects, engineers, and geomorphologists may be needed to fully assess aesthetics, habitat, classify stream characteristics, and design flood control structures.

There were only two disadvantages of using the RCHARC model that were discussed. The disadvantages included the following (Peters 1994; Peters et al. 1995):

- Compared with a HEC-2 study, an RCHARC analysis is slightly more complex. Water surface elevation and cross-sectional geometry from HEC-2 must be reformatted and processed for input into RCHARC.

- The RCHARC procedure does not provide a quantitative means of evaluating comparison reaches. All evaluations are qualitative.

It was determined that the RCHARC model was relatively simple to use and was a credible means to evaluate aquatic habitat between two reaches. There were several recommended enhancements to the RCHARC process. The enhancements included the following (Peters 1994; Peters et al. 1995):

- It is recommended that at least some of the velocity-depth points across each cross section should be shot into the cross-sectional survey. Water surface elevation can be calculated from these points in addition to the bank stations.

- It is recommended that the addition of other stream variables such as bed material be added to the RCHARC approach.

- It is recommended that a spreadsheet approach be developed to implement RCHARC. The SAS programs which comprise the RCHARC computer model aspect of RCHARC require much output/input data restructuring. A spreadsheet would be more user friendly and efficient.

- It is recommended that a quantitative element be added to the RCHARC analysis. The bivariate plots used in the Rapid Creek analysis were effective as visualization tools, but a quantitative statistical comparison of the reaches would be an improvement. Quantitative results would be useful in evaluating habitat design alternatives.

The RCHARC procedure

Ten steps must be performed to apply the RCHARC process to a stream. The process is presented in a flowchart as Figure 3. The first step in applying the RCHARC to a river system is to locate and characterize the CSRS based upon a target habitat. It is, therefore, essential that the data to be collected include information that will lead to channel geometry, stream hydrology, stage-discharge relationships, and depth and velocity distributions (Fischenich et al. 1993). Macrohabitat data should also be collected to characterize the CSRS. Macrohabitat variables may include water temperature, sediment load, bed load, dissolved oxygen, and bed material samples.

The next step is to locate the restoration reach. Data may be collected prior to restoration to determine preproject microhabitats and macrohabitats

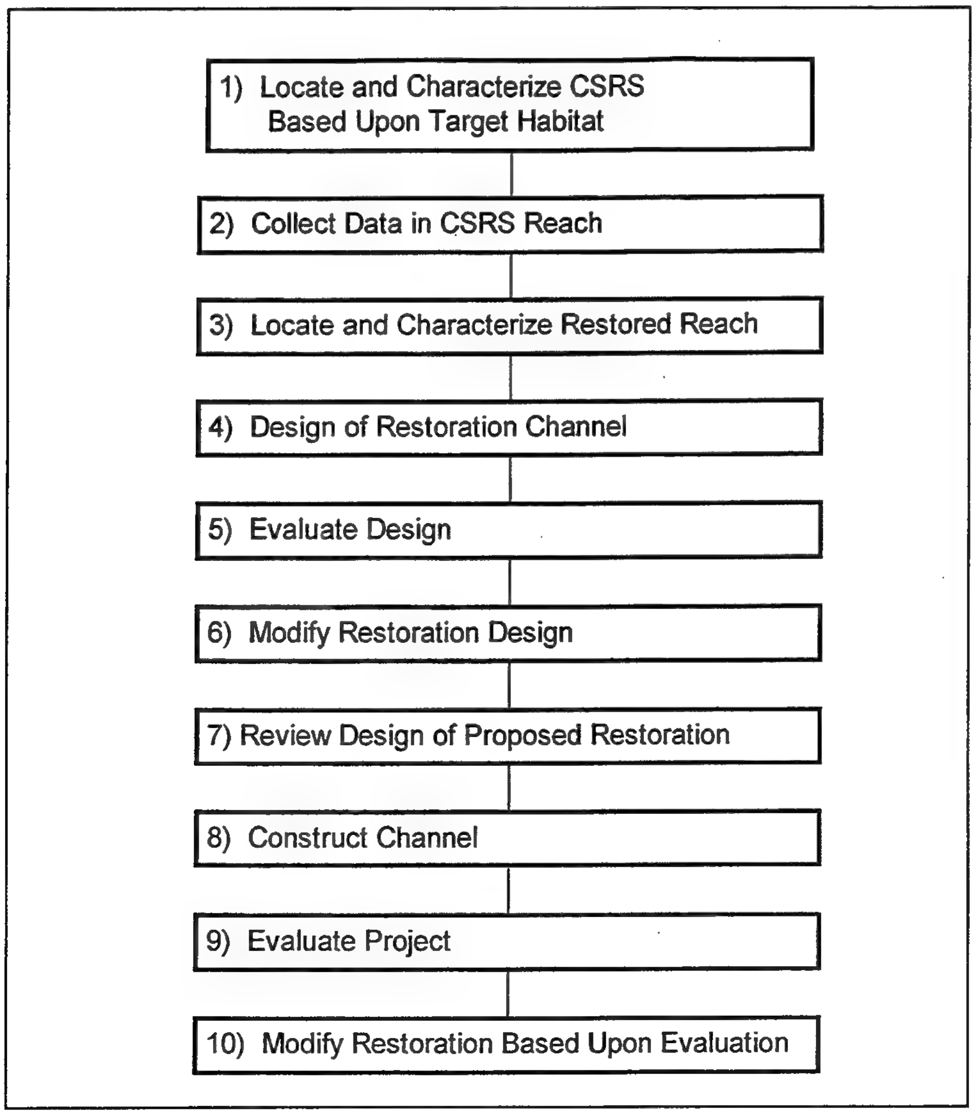

Figure 3. RCHARC step-by-step process

and provide a basis for comparison. The design team can then complete a preliminary design of the restored reach. The initial channel restoration design should be evaluated for flood capacity and habitat compatibility. Evaluation of the channel flood capacity can be achieved by performing a HEC-2 analysis of the newly designed channel. Evaluation continues by applying the RCHARC program to the proposed restored channel. The design is then modified until the design team determines an acceptable degree of similarity between the CSRS and the restored reach.

The proposed design is submitted for review by the appropriate review entities. Once approved, the final design is constructed. Upon construction, microhabitat and macrohabitat data must again be collected. The as-built restored reach and CSRS data are input into RCHARC to determine the actual degree the similitude between the two reaches. The restored reach can be modified as deemed necessary.

Backwater Computational Program (HEC-2)

A backwater computational program is routinely used to compare the flood capacity of the CSRS to the flood capacity of the restored reach at discharges and water surface elevations other than those observed during data collection. HEC-2 (Hydrologic Engineering Center 1990) is a one-dimensional program and may be integrated into the RCHARC process. The HEC-2 program should be operated with field data to calibrate the program. The program calculates water surface elevations throughout the stream assuming steady, gradually varied flow. The HEC-2 program cannot directly assess habitat. However, it can be used to compute the parameters that influence habitat. The RCHARC program ultimately uses the depths at each of the cross sections that can be obtained from the output of the HEC-2 simulations. A complete description in the use of HEC-2 in the RCHARC process is presented by Peters et al. (1996) and Peters (1994).

Canberra Metric Coefficient

The Canberra metric coefficient is a measure of dissimilarity often used by professionals in the biological community. The coefficient was developed by Lance and Williams (1966) and was originally termed a nonmetric coefficient. Its metric properties were later discovered and the coefficient was renamed Canberra metric (Lance and Williams 1967). The Canberra metric is a series of fractions that represent the interentity agreement of each attribute. It, therefore, has a built-in standardization of the attributes (Boesch and Swartz 1977). The coefficient is used because occurrences in nature often exhibit large population differences in one location. These differences dominate other coefficients. The Canberra metric is unique in that the large population differences in one location only contribute to one fraction of the entire coefficient.

The Canberra metric coefficient can be expressed as:

$$C.M. = \frac{1}{n} \sum_{1}^{n} \frac{|x_{1_i} - x_{2_i}|}{(x_{1_i} + x_{2_i})} \tag{4}$$

where

n = total number of fractions

x_{1_i} = first variable to be compared

x_{2_i} = second variable to be compared

The coefficient ranges from a value of zero to one with a value of one representing a perfect dissimilarity. To compute a similarity coefficient, it is possible to subtract the Canberra metric coefficient from one. The similarity coefficient will also range from a value of zero to one; however, one will represent perfect similarity.

It is possible that both the first, x_1, the second term, x_2, in Equation 4 may be zero. These terms may be neglected, but the coefficient is no longer a metric (Stephenson, Williams, and Cook 1972). When only one element, either x_1 or x_2, in Equation 4 is zero, the resulting fraction is unity. The result of unity appears no matter how large the difference between the two elements; therefore, a difference in the elements of 1,000 to 0 will appear equally dissimilar as 0.001 to 0. A closer representation of dissimilarity is determined by replacing the zero element with a number sufficiently small as to not be significant (Clifford and Stephenson 1975).

Bed Material Comparison

Bed material, or substrate in some definitions, is a component of aquatic microhabitat. The bed material is comprised of an armor layer and substrate. The armor layer is the uppermost surface layer of bed material in the streambed. The thickness of the armor layer is dependent on the diameter of each individual grain comprising the surface layer of bed material. The thickness of the armor layer, therefore, is not constant. The substrate is defined as the bed material that exists directly below the armor layer (Abt, Florentin, and Watson 1995). The bed material is defined as the material that comprises both the armor and substrate layers. PHABSIM includes the component of bed material in its habitat evaluation. The bed material is incorporated into the channel index variable which is a component of the WUA in the equation presented in Equation 1. The bed material, therefore, comprises one-sixth of the total weight needed to determine the WUA.

Hogan (1993) discussed the amount of bed material needed to compute the gradation of bed material with statistical acceptability. He compared various bed sampling methods and computed the amount of bed material needed to be confident about gradation results. Hogan (1993) did not offer a method to quantitatively compare various gradation curves. A method commonly used to evaluate the similarity of the bed material is a qualitative analysis of the sediment curves. The analysis is performed by superimposing the sediment curves on consistently scaled graphs, which allows a visual comparison of the similarities and differences. However, this method does not provide quantitative results, and the interpretation is left to the discretion of the design team.

3 Site Descriptions and Data Collection

The RCHARC process may be employed to evaluate the success of a stream restoration project. To do so, it is necessary to select a CSRC with the aquatic characteristics that are desired for the restored reach. To evaluate the reliability of the RCHARC process, a stream was selected which included (a) a natural or undisturbed stream (CSRS) reach, (b) a restored reach, and (c) a degraded stream reach. Each reach is considered to be a high quality trout fishery; however, the target habitat of the natural reach was determined to be a pristine habitat in which trout thrive. The site had to be accessible and exhibit hydraulic diversity (Abt, Florentin, and Watson 1995). In cooperation with the Colorado Division of Wildlife Habitat Resources Section, Goose Creek, located in southwestern Colorado, was selected for evaluation as it exhibits the characteristic diversity desired to fully evaluate the RCHARC process.

Site Location

Goose Creek is located approximately 97 km west of Alamosa, CO, in Mineral County. The location of Goose Creek is presented in Figures 4 and 5. The headwaters of Goose Creek originate in the Weminuche Wilderness on the upper plateau in the San Juan mountain range (Abt, Florentin, and Watson 1995). Goose Creek empties into the Rio Grande River immediately upstream of Wagon Wheel Gap, Colorado. The section of Goose Creek assessed in this study extends from the wilderness boundary to the confluence of Goose Creek with the Rio Grande River. The stream study segment is approximately 11.5 km in length.

These separate reaches were selected for observation and field characterization in the study segment of Goose Creek. The natural reach (CSRS), presented in Figure 6, was located immediately downstream of the wilderness boundary. The restored reach was located near the midsection of the study segment, and the degraded reach was located about 2 km downstream from the restored reach as presented in Figure 7. Each reach was approximately

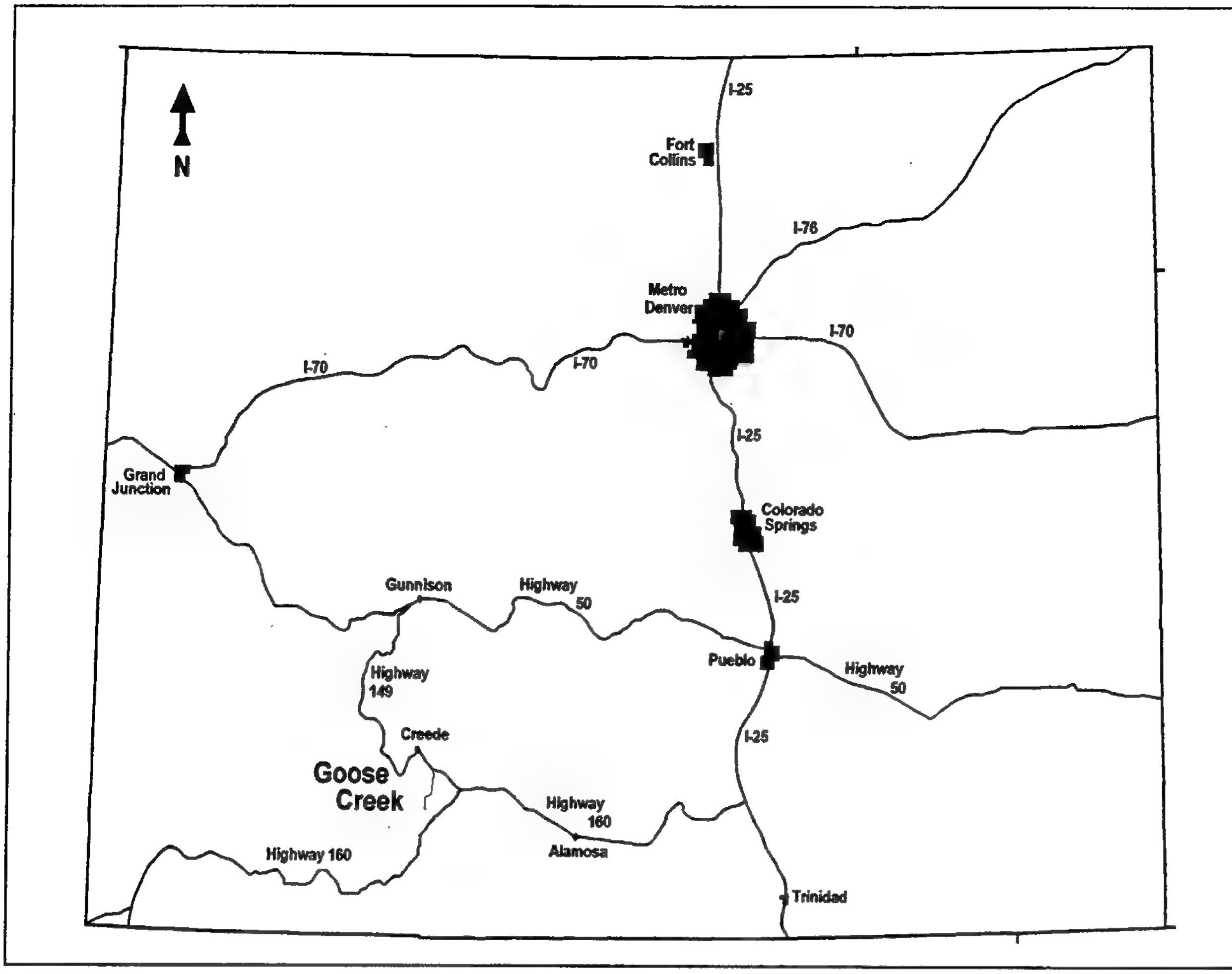

Figure 4. Colorado state map

275 m in length and was divided into 10 cross sections; adjacent cross sections were spaced three to five stream widths apart.

Reach Descriptions

Each reach in the study segment of Goose Creek was unique. The natural reach had not been structurally modified other than by natural processes. The natural reach bisects private property but is rarely accessed. The seclusion of the reach has led to an environment that is primarily controlled by the natural flows and forces of the tributary watershed. The natural reach has a bed slope of 0.0197. The flow is contained in one channel and has a stable cobble bed. The average width of the channel is approximately 8.41 m. A photograph of the natural reach is presented as Figure 8. The natural reach typically exhibited a higher average velocity than that of either the restored or the degraded reach. The rapid flow contributed to a relatively small cross-sectional flow

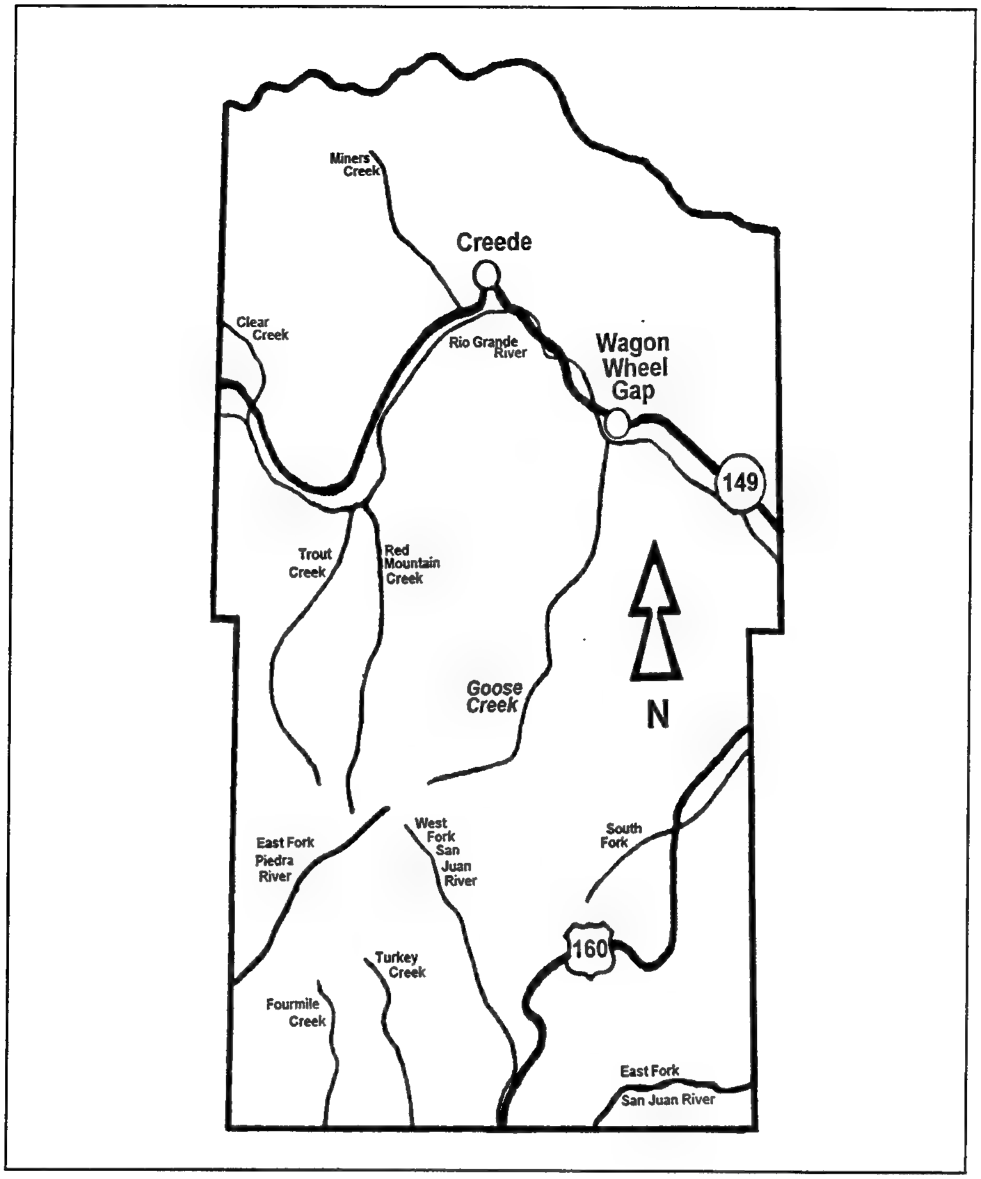

Figure 5. Mineral county map

area. There is a diversity of pine trees, willows, and aspen trees along the banks of the natural reach.

The mid reach was restored by a property owner in an effort to develop a haven for fishing. The adjacent land use is pasture. Prior to restoration, cattle degraded the streambanks and vegetation, thereby impacting the natural aquatic habitat. A photograph of the restored reach is presented as Figure 9. Restoration was required to return the stream to a habitat conducive to aquatic biota. Restoration features include drop structures, boulder and log bank protection, and willow plantings indicative of the natural reach. The bed slope of the restored reach is 0.0125. The stream in the restored reach indicated a greater meander pattern than the natural reach. The restored reach

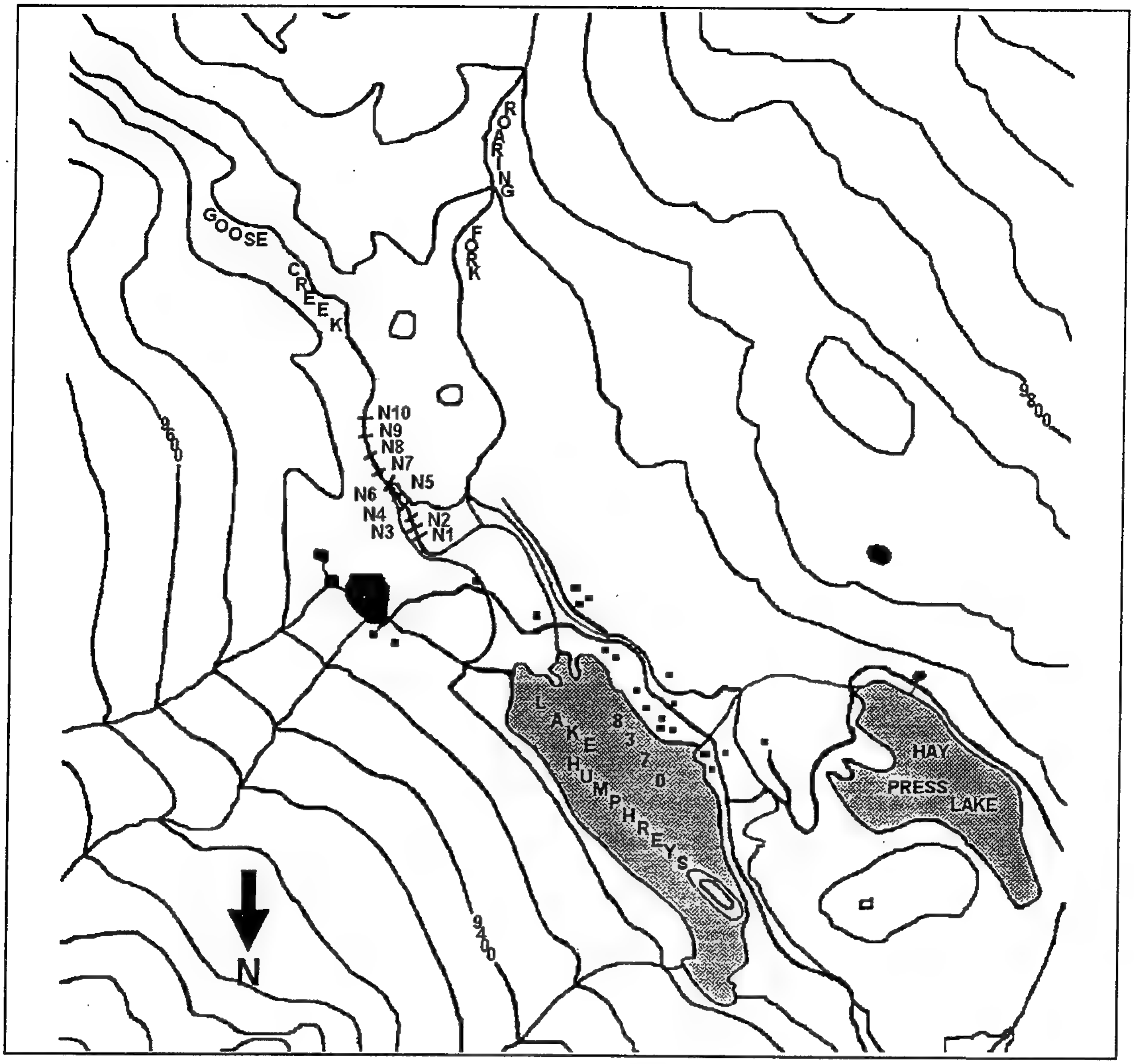

Figure 6. Natural reach

has a top width of approximately 8.66 m. The boulder-lined meanders encourage the stream to remain in one channel, while large boulders were placed in the typically small cobble and course gravel bed. Grasses and willow plantings dominate the banks of the restored reach.

The degraded reach is located adjacent to an abandoned mine. The tailings from the mine encroach into the stream and have contaminated the habitat. The stream banks have severely eroded, and bank vegetation has not survived in the adverse environment. The degraded stream reach is unstable with a tendency to braid (shallow depth and a large top width averaging about 11.05 m). The channel is inundated with algae and moss, and the bed is

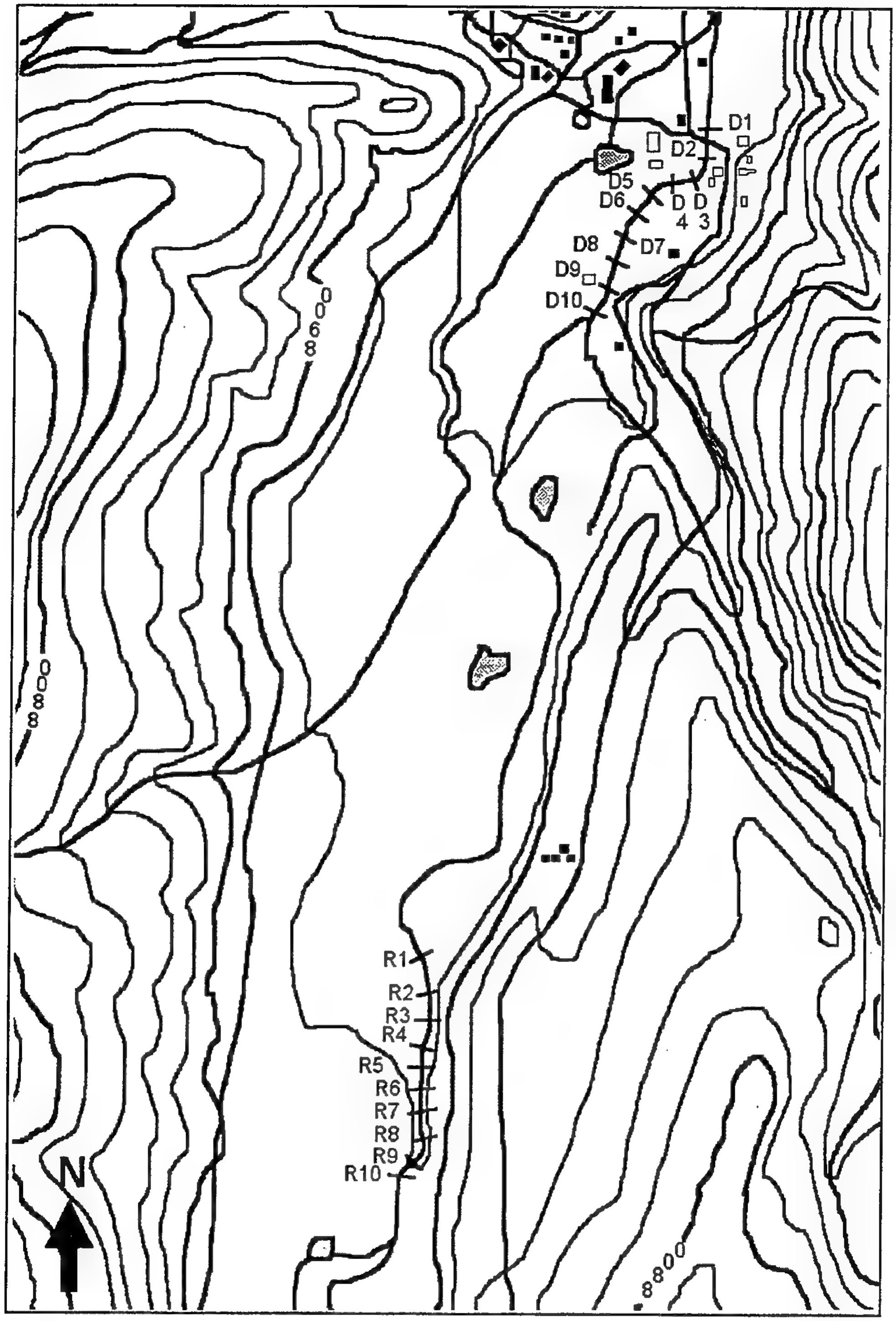

Figure 7. Restored and degraded reaches

composed of small cobbles and coarse gravel. A photograph of the degraded section is presented in Figure 10. Descriptions of individual cross sections in each of the three reaches are presented in Appendix A.

Figure 8. Photograph of natural reach

Figure 9. Photograph of restored reach

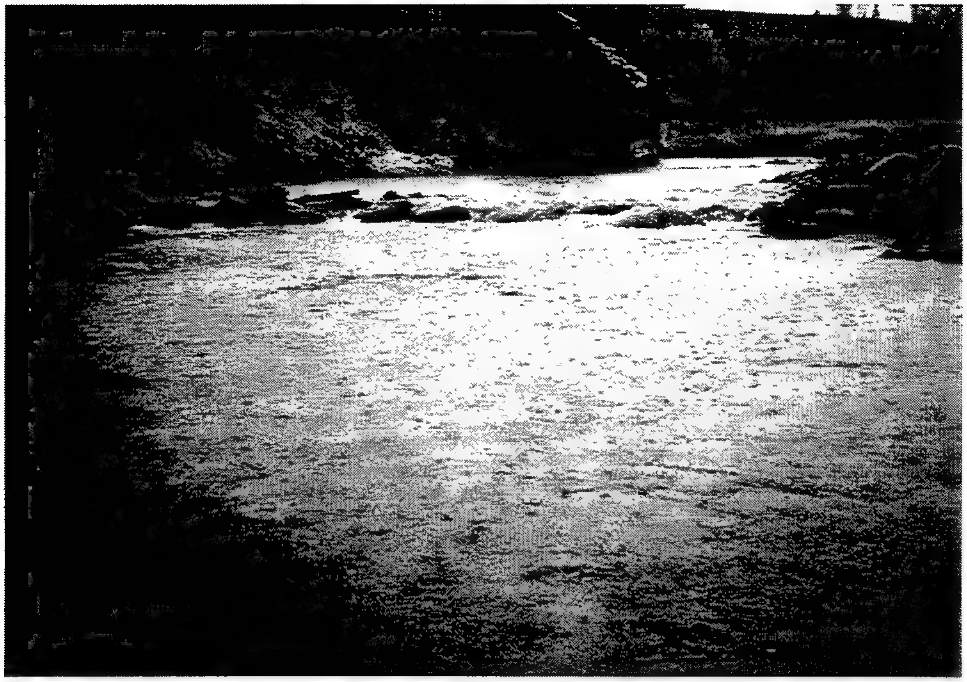

Figure 10. Photograph of degraded reach

Data Collection

Macrohabitat and microhabitat data were collected in each reach for input into RCHARC. Relevant macrohabitat information was collected for comparing reach similarity and included water temperature, dissolved oxygen, bedload and suspended sediment load, and channel slopes. The microhabitat variables included the stream hydraulic characteristics of depth, velocity, and cross-section geometry which were collected at each cross section. Additional microhabitat data obtained included armor layer and substrate character for each of the three reaches. Microhabitat variables are then input into RCHARC for evaluation.

Macrohabitat data

Macrohabitat data were collected in every reach to allow a quantitative comparison of macrohabitat similarity. Water temperatures and dissolved oxygen were measured in each reach at one cross section using a dissolved oxygen meter. The meter measured the temperature to an accuracy of ±0.1 °C. Five dissolved oxygen content measurements were obtained at the same cross section subsequent to the temperature. The locations of the readings were evenly spaced across the cross section. The water temperature and the dissolved oxygen were determined using a YSI Incorporated Model 50B dissolved oxygen meter with a Model 5492A battery pack with an accuracy of ±0.1 mg/L.

A bedload sample was extracted in each reach. A Helly-Smith type bedload sampler was used to collect the samples. Suspended sediment samples were also obtained in each reach using a DH-48 sampler. The channel slope was determined from a reach survey using a total station instrument. The total station was accurate to ± 10 s. The accuracy of the survey in the vertical direction for an entire reach was ± 1.5 cm. The channel slope of each reach was determined using the thalwegs of each cross section and survey points of visually noticeable changes in channel slope. The use of product names in describing data collection methods is provided only to aid in the description and is not an endorsement.

Microhabitat data

Microhabitat characteristics of the three reaches were collected for input into the RCHARC model. Each cross-sectional top width was minimally divided into 20 equal divisions. Flow velocity and depth pairs were measured and recorded at each division in each cross section. Velocity measurements were obtained with a Marsh-McBirney flowmeter, which is accurate to ± 0.015 m/s. When the water depth at a measurement point was less than 0.31 m, a velocity was taken at 0.6 of the water depth (U.S. Department of the Interior 1984). The velocity at 0.6 of the water depth was considered the mean velocity for that cell. When the water depth was greater than or equal to 0.31 m, velocities were obtained at 0.8 to 0.2 of the depth and averaged together to determine a mean velocity for the cell (U.S. Department of the Interior 1984). At least 200 velocity-depth pairs were recorded in each reach.

Cross-section geometry was determined with a total station survey. Survey points were taken at points where changes of slope on the bank and bed occurred. Seven to ten survey points were used to define each cross section. A complete quantitative description of the cross section was obtained by including the depths measured from the water surface to the channel bed at each velocity-depth measurement point. Velocities were determined at survey points by linearly interpolating between velocity-depth measurement points as defined by:

$$V_{SP_i} = \frac{(X_{VP_j} - X_{SP_i}) * V_{VP_j} + (X_{SP_i} - X_{VP_{j-1}}) * V_{VP_{j-1}}}{(X_{VP_j} - X_{VP_{j-1}})} \tag{5}$$

where

V_{SP} = velocity at a specific survey point

X_{VP} = horizontal distance from bank of a velocity point

X_{SP} = horizontal distance from bank of survey point

V_{VP} = velocity at a velocity point

$_J$ = velocity point before survey point

$_{J+1}$ = velocity point after survey point

Figure 11 presents the locations where velocities were determined using Equation 5.

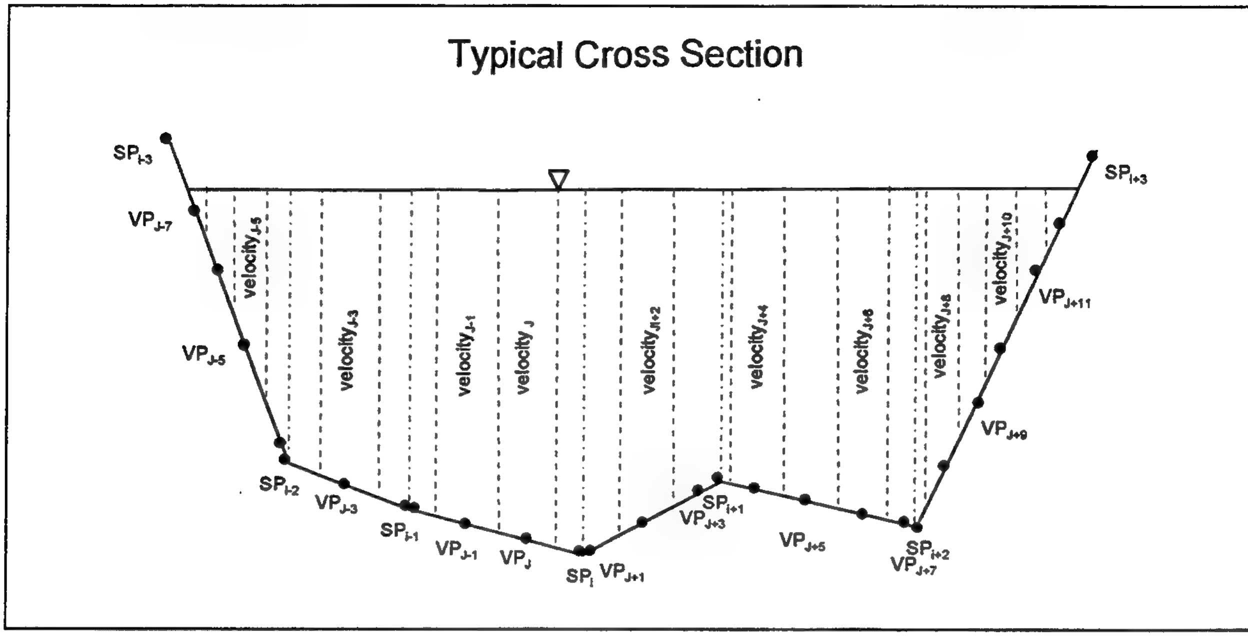

Figure 11. Velocity and survey points

The microhabitat characterization included armor layer and substrate samples from each reach. The bed material samples were extracted at the same location as the temperature and dissolved oxygen. Armor layer and substrate samples were obtained using a Milhous drum sampler in accordance with Hogan (1993). Approximately 45 kg of bed material was removed at each location.

Presentation of Collected Data

A summary of the data collected at Goose Creek will be presented. Since the number of microhabitat data required to evaluate the RCHARC process is quite extensive, the complete set of microhabitat data is presented in Appendix B.

Macrohabitat data presentation

Macrohabitat data were collected at each of the three reaches to verify similitude between the reaches. Twenty-four years of historical flows for

Goose Creek were obtained from the flow records recorded at a gauging station located approximately 300 m downstream of the degraded reach. The average daily flow rate was calculated to be 19.6 m^3/s. The maximum instantaneous flow past the gauging station was recorded on June 18, 1995, and was 310 m^3/s.

The water temperature and dissolved oxygen for each reach are presented in Figures 12-14. The average temperature measured in the three reaches was 18.2 °C. The average dissolved oxygen contents in the natural (CSRS), restored, and degraded reach were 8.22, 7.92, and 7.16 mg/L, respectively. The respective oxygen contents reflect the suitability of each reach to support a trout population. The natural reach contained the highest level of dissolved oxygen, and the degraded reach exhibited the lowest level of dissolved oxygen.

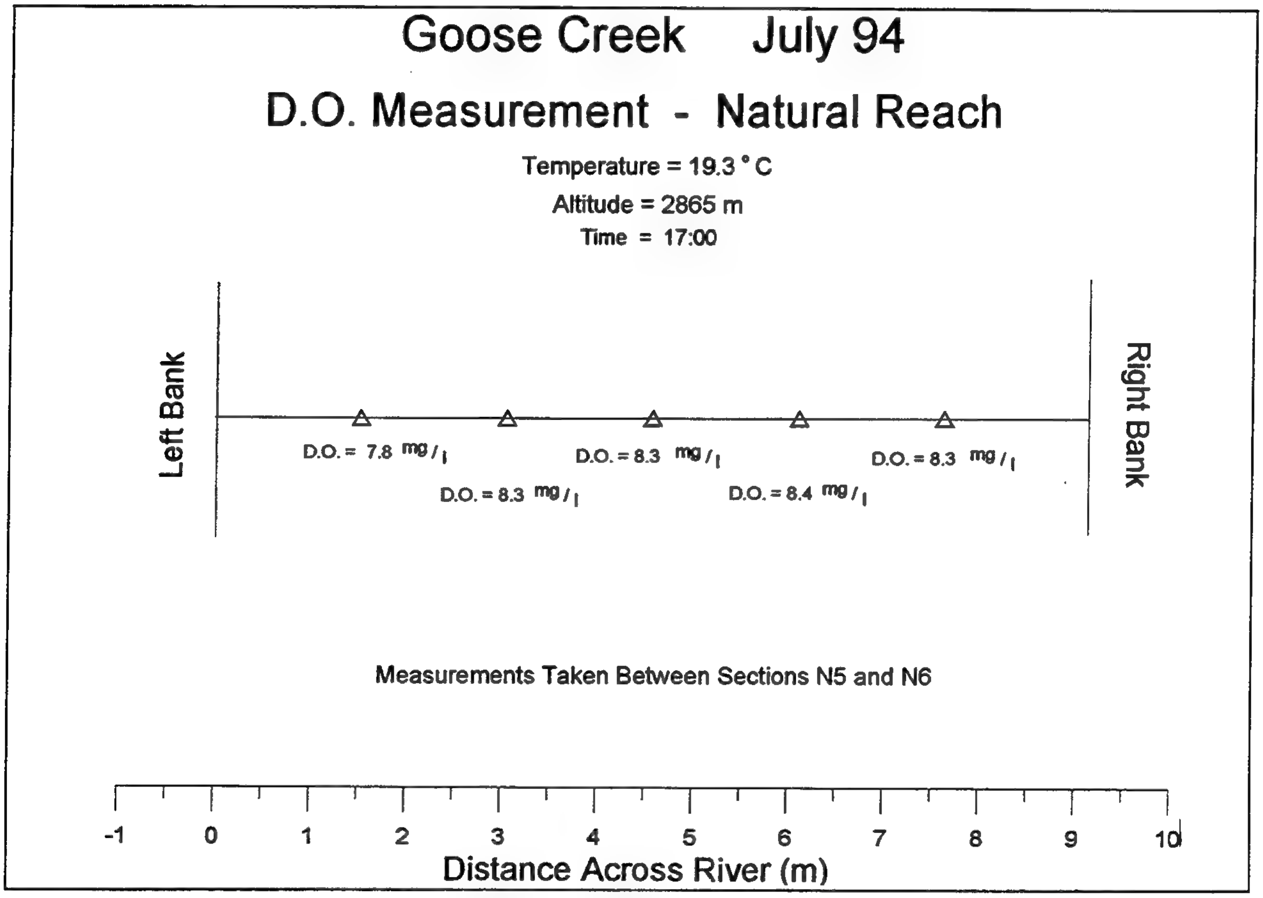

Figure 12. Natural reach—water temperature and dissolved oxygen content

The bedload transport rate is presented in Table 2, and suspended sediment transport rate is presented in Table 3. The average suspended sediment transport for the natural (CSRS), restored, and degraded reach was 686.25, 921.16, and 1,137.93 kg/day, respectively. Although the natural reach has a

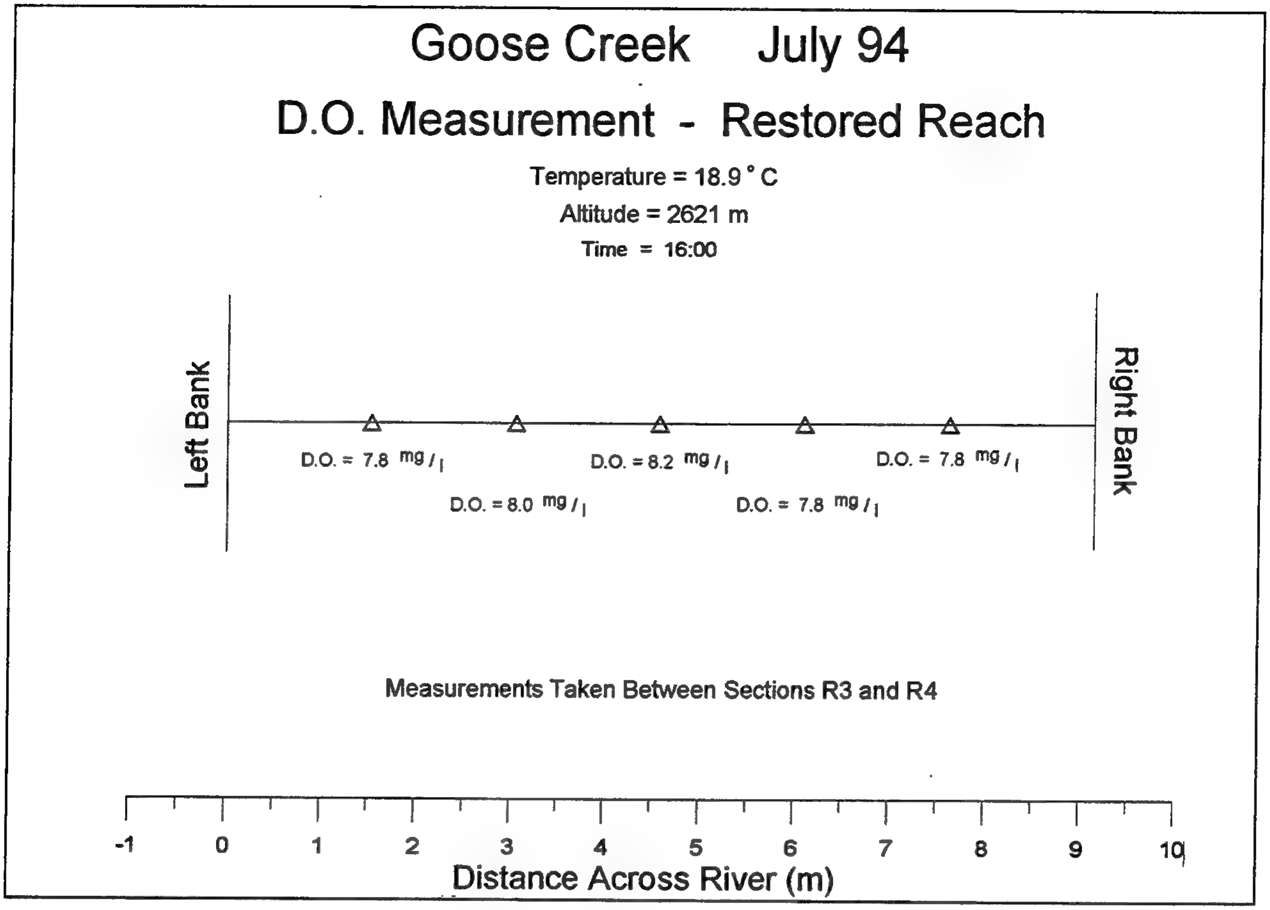

Figure 13. Restored reach—water temperature and dissolved oxygen content

steeper average bed slope, 0.0197 m/m, there is less sediment available for transport because of the dense vegetation adjacent to the natural reach. The restored reach has a relatively moderate average bed slope, 0.0125 m/m, but exhibits a lower density of vegetation leading to a greater suspended sediment transport rate. The degraded reach has the flattest slope, 0.0101 m/m, but the banks have sparse vegetation, thereby supplying vast amounts of sediment for transport. The channel slopes in the three reaches are compared in Table 4, and the thalwegs of each channel are presented for comparison in Figure 15. The average slope was computed by dividing the difference in elevations by the total stream length.

Microhabitat data presentation

Microhabitat data were collected in the three reaches at Goose Creek for input into RCHARC. The high, low, and average flow depths and velocities are presented for each cross section in each reach in Tables 5-7. The average velocity for the natural reach was 0.486 m/s in July and 0.523 m/s in September at average depths of 0.22 and 0.21 m, respectively. The average velocity

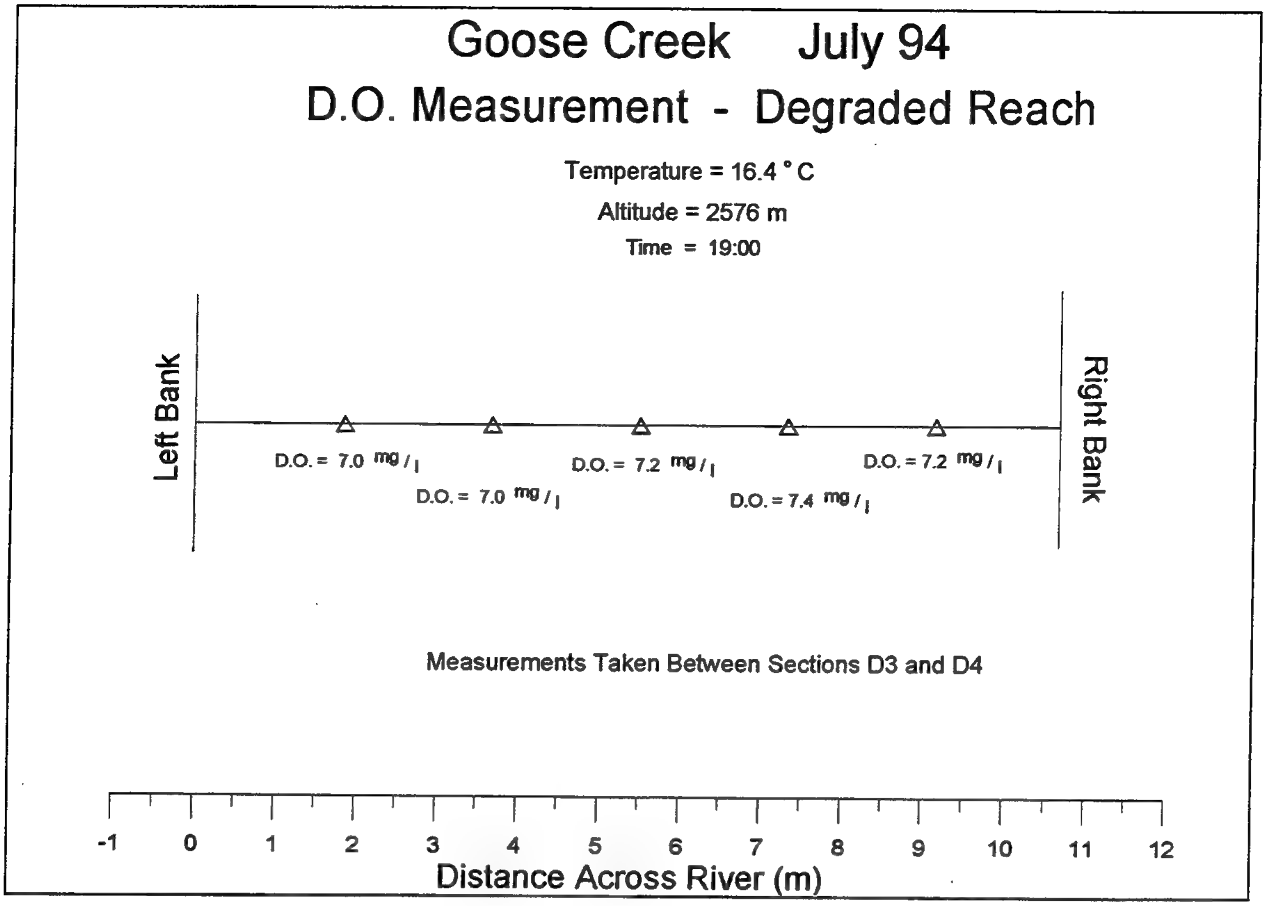

Figure 14. Degraded reach—water temperature and dissolved oxygen content

Table 2
Bed-Load Discharge

	Sample Size, g	Time, min	Sediment Transport, kg/day
Natural reach	2.217	20	0.15962
Restored reach	0.133	20	0.00958
Degraded reach	0.184	20	0.01325

for the restored reach was 0.471 m/s at a depth of 0.26 m in July and 0.497 m/s at a depth of 0.27 m in September. In July, the degraded reach exhibited an average velocity of 0.366 m/s at a depth of 0.21 m, and in September had an average velocity of 0.312 m/s at a depth of 0.21 m. The cross-sectional average velocity was determined by summing the total of the cell averaged velocities multiplied by the width and depth of the cell for each cell and dividing the sum by the width multiplied by the depth of each cell as expressed by:

Table 3
Suspended Sediment Load

Sample Number	Sediment Concentration by Volume, mg/L	Sediment Transport, kg/day	Based on, cm
#1 Natural	6.00	411.75	10.45
#2 Natural	14.00	960.75	10.45
#3 Restored	12.50	975.39	11.88
#4 Restored	11.11	866.93	11.88
#5 Degraded	10.00	738.20	11.24
#6 Degraded	20.83	1,537.66	11.24

$$\frac{\sum_{i=1}^{n} \overline{v}_i * w_i * d_i}{\sum_{i=1}^{n} w_i * d_i} \qquad (6)$$

where

v_i = divisional averaged velocity of division

w_i = width of division

d_i = depth of flow at division

n = total number of divisions in cross section

Both the armor layer and the substrate from the channel in each reach were sampled. The samples were sieved and recorded. The median grain size, d_{50}, for the armor layer in the natural, restored, and degraded reach is 100, 70, and 80 mm, respectively. The d_{50} for the substrate in the natural, restored, and degraded reach is 100, 40, and 40 mm, respectively. The resulting gradation curves for the armor layer and substrate are presented as Figures 16 and 17, respectively.

Table 4
Reach Bed Slopes

Cross Section	Channel Slope
Natural Reach or CSRS	
N1	0.0102
N2	0.0030
N3	0.2820
N4	0.0074
N5	0.0348
N6	0.0088
N7	0.1132
N8	0.0057
N9	0.0341
N10	0.0114
Average	0.0197
Restored Reach	
R1	0.0146
R2	0.0121
R3	0.0120
R4	0.0125
R5	0.0178
R6	0.0107
R7	0.0033
R8	0.0079
R9	0.0487
R10	0.0092
Average	0.0125
Degraded Reach	
D1	0.0013
D2	0.1091
D3	0.0046
D4	0.0037
D5	0.0227
D6	0.0088
D7	0.0079
D8	0.0040
D9	0.0037
D10	0.0741
Average	0.0101

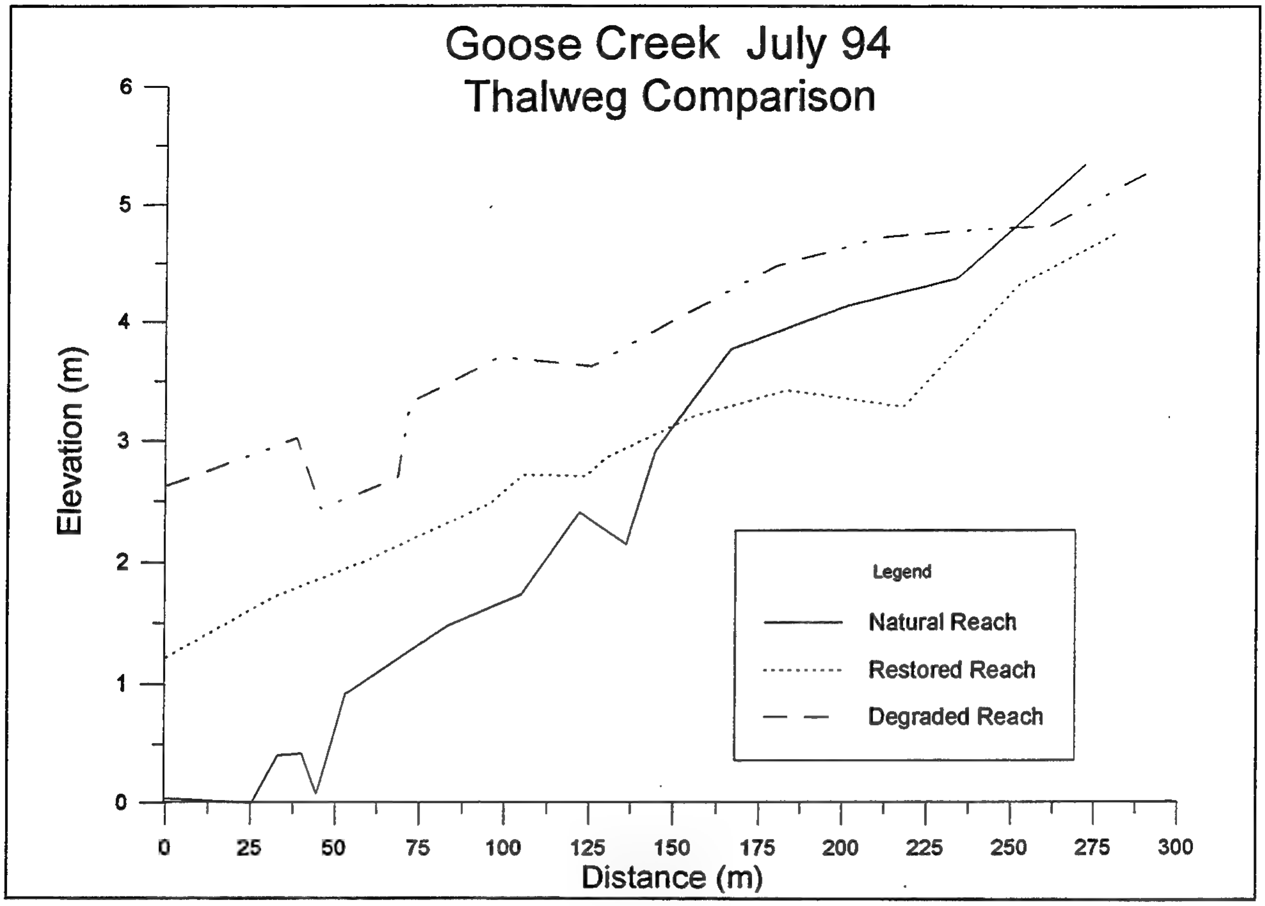

Figure 15. Reach thalweg comparison

Table 5
Depth and Velocity Data in the Natural Reach

Cross Section	Average Velocity m/s	High Velocity m/s	Low Velocity m/s	Number of Divisions	Average Depth m	High Depth m	Low Depth m
July							
N1	0.450	0.808	0.000	20	0.21	0.49	0.00
N2	0.379	0.824	0.000	19	0.33	0.61	0.00
N3	0.704	1.241	0.000	20	0.19	0.31	0.00
N4	0.584	1.405	0.000	22	0.15	0.37	0.00
N5	0.541	1.149	0.000	22	0.21	0.52	0.00
N6	0.191	0.599	-0.116	21	0.42	0.64	0.00
N7	0.472	0.942	0.000	21	0.14	0.24	0.00
N8	0.627	1.183	0.000	21	0.20	0.31	0.00
N9	0.457	0.933	0.000	21	0.20	0.55	0.00
N10	0.454	0.805	0.000	24	0.18	0.34	0.00

(Continued)

Table 5 (Concluded)							
Cross Section	Average Velocity m/s	High Velocity m/s	Low Velocity m/s	Number of Divisions	Average Depth m	High Depth m	Low Depth m
September							
N1	0.367	0.724	0.000	21	0.17	0.43	0.00
N2	0.394	0.893	0.000	21	0.31	0.55	0.00
N3	0.730	1.426	0.000	21	0.18	0.31	0.00
N4	0.542	0.991	0.000	21	0.17	0.37	0.00
N5	0.528	1.009	0.000	19	0.19	0.46	0.00
N6	0.191	0.526	-0.143	20	0.37	0.58	0.00
N7	0.478	0.866	0.000	21	0.11	0.24	0.00
N8	0.863	1.265	0.000	23	0.18	0.37	0.00
N9	0.583	0.960	0.000	20	0.21	0.49	0.00
N10	0.551	0.920	0.000	21	0.17	0.37	0.00

Table 6 Depth and Velocity Data in the Restored Reach							
Cross Section	Average Velocity m/s	High Velocity m/s	Low Velocity m/s	Number of Divisions	Average Depth m	High Depth m	Low Depth m
July							
R1	0.585	0.969	0.000	22	0.27	0.52	0.00
R2	0.243	0.390	-0.043	21	0.31	0.46	0.00
R3	0.624	1.082	0.000	19	0.21	0.37	0.00
R4	0.551	0.981	0.000	22	0.17	0.37	0.00
R5	0.380	0.847	0.000	22	0.23	0.76	0.00
R6	0.389	0.591	0.000	21	0.22	0.46	0.00
R7	0.555	0.837	0.000	22	0.22	0.43	0.00
R8	0.189	0.445	0.000	21	0.54	1.13	0.00
R9	0.619	1.234	0.000	22	0.21	0.34	0.00
R10	0.573	1.122	0.000	21	0.20	0.34	0.00
September							
R1	0.690	1.259	0.000	23	0.23	0.43	0.00
R2	0.329	0.613	0.000	24	0.32	0.49	0.00
R3	0.617	1.073	0.000	22	0.22	0.40	0.00
R4	0.658	1.585	0.000	21	0.16	0.29	0.00
R5	0.366	0.668	0.000	22	0.30	0.82	0.00
R6	0.407	0.680	0.000	21	0.26	0.52	0.00
R7	0.509	0.922	0.000	21	0.26	0.52	0.00
R8	0.177	0.480	0.000	20	0.55	1.07	0.00
R9	0.610	1.283	0.000	21	0.21	0.37	0.00
R10	0.603	1.222	0.000	21	0.21	0.34	0.00

Table 7
Depth and Velocity Data in the Degraded Reach

Cross Section	Average Velocity m/s	High Velocity m/s	Low Velocity m/s	Number of Divisions	Average Depth m	High Depth m	Low Depth m
July							
D1	0.275	0.646	0.000	25	0.21	0.41	0.00
D2	0.300	0.771	0.000	24	0.20	0.38	0.00
D3	0.376	0.637	0.000	21	0.22	0.37	0.00
D4	0.391	0.637	0.000	21	0.28	0.52	0.00
D5	0.464	0.914	0.000	22	0.17	0.34	0.00
D6	0.401	0.860	0.000	23	0.15	0.30	0.00
D7	0.357	0.607	0.000	22	0.19	0.32	0.00
D8	0.311	0.497	0.000	21	0.21	0.43	0.00
D9	0.306	0.693	0.000	21	0.26	0.49	0.00
D10	0.476	0.853	0.000	21	0.20	0.34	0.00
September							
D1	0.293	0.692	0.000	21	0.20	0.37	0.00
D2	0.269	0.637	0.000	20	0.21	0.46	0.00
D3	0.300	0.732	0.000	21	0.22	0.37	0.00
D4	0.344	0.555	0.000	20	0.25	0.46	0.00
D5	0.298	1.015	0.000	21	0.16	0.34	0.00
D6	0.201	0.969	0.000	21	0.16	0.27	0.00
D7	0.297	0.512	0.000	21	0.20	0.29	0.00
D8	0.236	0.640	0.000	21	0.21	0.43	0.00
D9	0.360	0.931	0.000	21	0.28	0.52	0.00
D10	0.523	0.951	0.000	20	0.19	0.30	0.00

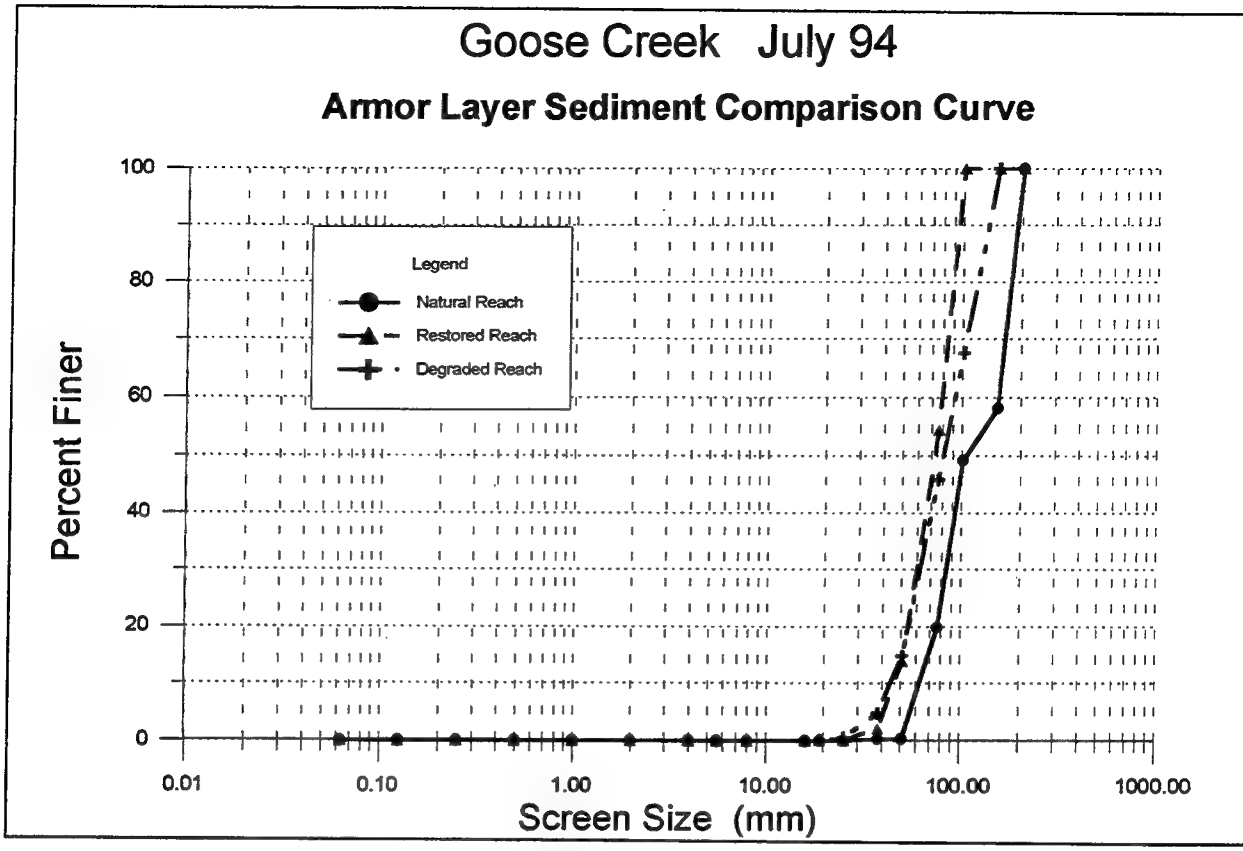

Figure 16. Armor layer gradation comparison

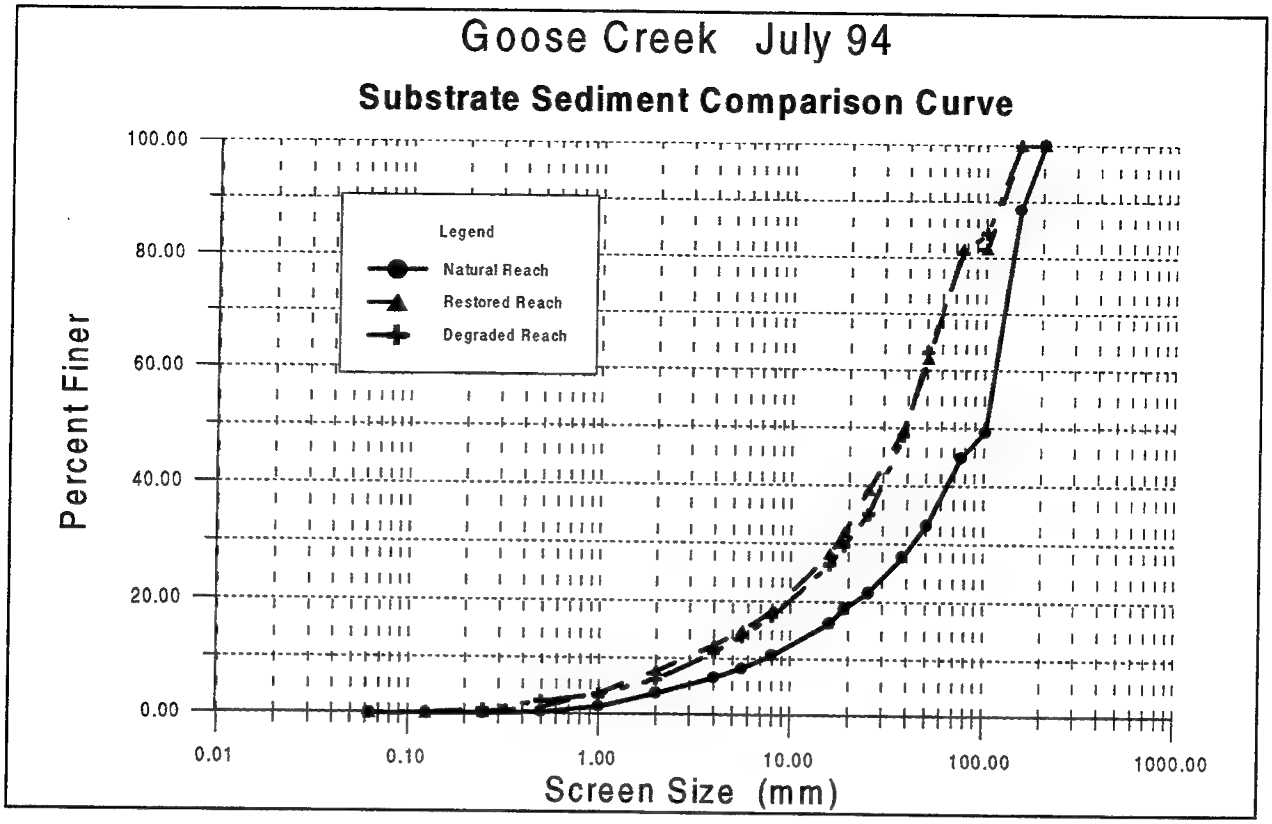

Figure 17. Substrate gradation comparison

4 Analysis Using RCHARC

The data collected in the three reaches at Goose Creek were input into RCHARC to compare the similarity of the reaches. The results of the RCHARC simulations were analyzed, and modifications are proposed to enhance RCHARC.

RCHARC Habitat Evaluation Process

Data collected at Goose Creek were segmented for input into RCHARC. The macrohabitat data were compared to ensure the reaches were similar. Although the reaches exhibited different slopes, dissolved oxygen contents and sediment transport characteristics as presented in Chapter 3, it was determined that the differences were not significant and the macrohabitats were similar. Thus, RCHARC could be used to assess the degree of similarity of the reaches based on the microhabitat components. The microhabitat data were compiled for evaluation. The survey data and the velocity data were combined to produce depth-velocity pairs, and the bed material samples were sieved and analyzed.

HEC-2 was calibrated by inputting the cross-sectional geometry, flow rates, and an assumed Manning's n value into the model. The HEC-2 program was executed, and the calculated water surface elevations at each cross section were compared to the field-observed water surface elevations. The assumed Manning's n value(s) was then adjusted until the calculated water surface elevations were similar ($\pm$0.07 m) to the observed water surface elevations.

The water surface elevations from the HEC-2 output were then input, along with flow rate and the observed cross-sectional depth-velocity pairs, into RCHARC (IFG4). The IFG4 subprogram read the observed depth-velocity pairs for each reach to calculate calibrated depth-velocity pairs. The subprogram was initialized, and IFG4 generated simulated depth-velocity pairs for each cross section in each reach. The data sets were then converted from binary to ASCII using the LSTVDX program. The generated data set was then input and manipulated by RCHARC.

The RCHARC program requires input of depth-velocity pairs, the discharge of the stream for measured depths and velocities, stream lengths, and widths of depth-velocity pair cells. RCHARC organizes the data into habitat classifications described by Aadland (1993). The percent of total reach habitat is reported by RCHARC. The RCHARC program also generates a two-dimensional topo-plot of the depth-velocity pair distribution resulting from the depth-velocity pairs input into the program and computes a Canberra metric coefficient for the comparison reaches. A schematic of the process is presented as Figure 18.

Results of RCHARC Application

The microhabitat data for the natural, restored, and degraded reaches on Goose Creek were entered into the RCHARC process as described above. A summary table of results from the HEC-2 simulation is presented in Table 8. The data from Table 8 were used by IFG4 to generate simulated depth-velocity pairs for each reach, which were subsequently used by the RCHARC to develop plots and compute Canberra metric coefficients. The process is data intensive. Samples of the input and output for HEC-2 and IFG4, as well as a sample of the input for RCHARC, are presented in Appendix C.

The RCHARC program manipulated the input and produced a table that classified the data into mesohabitats (Aadland 1993) for each reach. The habitat classification for each reach is presented in Table 9. The RCHARC program rearranged the data into depth-velocity pairs and the percent of the total observations in the reach for each depth-velocity pair. A summary table of depth-velocity pairs for each reach is presented in Table 10. The program then produced a two-dimensional topo-plot of the depth-velocity pair distribution for each reach. The topo-plots are presented in Figure 19, Figure 20, and Figure 21 for the natural (CSRS) reach, the restored reach, and the degraded reach, respectively. The output was then input into a commercially available three-dimensional graphics program, Surfer (Golden Software, Inc. 1994). The surface plots for the natural (CSRS) reach, the restored reach, and the degraded reach are presented as Figure 22, Figure 23, and Figure 24, respectively.

Two stream reaches can be quantitatively compared using the RCHARC program. The program analytically compares the depth-velocity pairs and computes a Canberra metric coefficient which represents the degree of dissimilarity between the reaches. The similarity of the reaches can be computed by subtracting the Canberra metric coefficient from unity. The similarity coefficient ranges from zero to one, where one depicts a high degree of similarity between the reaches. The three reach comparisons (i.e., natural versus restored, etc.) were compared. The dissimilarity and similarity coefficients from these comparisons are presented in Table 11.

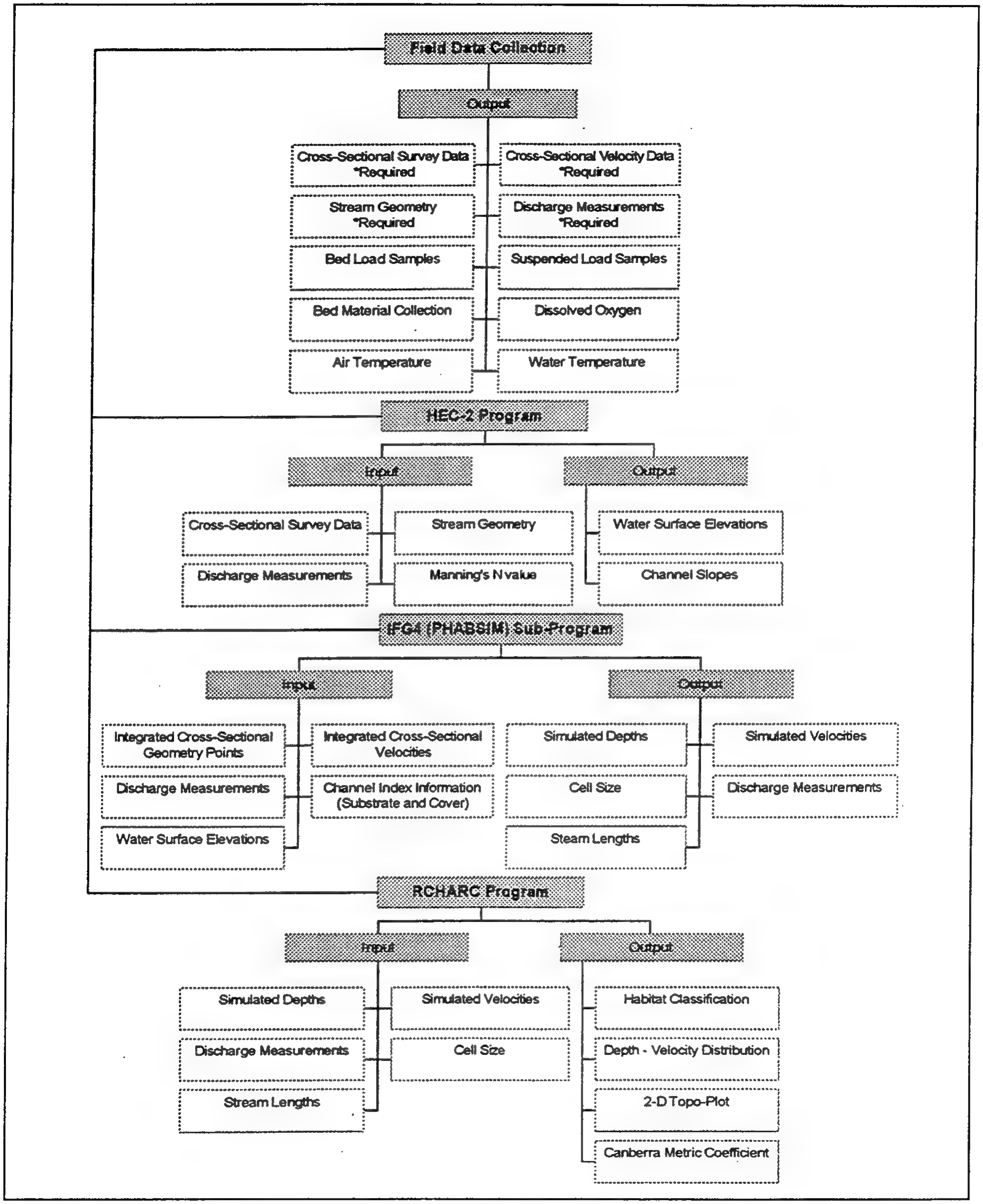

Figure 18. RCHARC methodology process

Table 8
HEC-2 Results

Cross Section	Channel Slope	Depth, m	Channel Velocity, m/s	Top Width, m	Distance Between Sections, m
Natural Reach (CSRS)					
N1	0.0102	0.378	0.442	12.631	--
N2	0.0030	0.543	0.457	4.362	25.213
N3	0.2820	0.210	1.180	4.807	27.075
N4	0.0074	0.366	0.488	7.163	29.428
N5	0.0348	0.405	0.539	7.013	21.714
N6	0.0088	0.485	0.320	8.135	30.212
N7	0.1132	0.177	0.933	9.815	30.331
N8	0.0057	0.369	0.335	13.052	34.506
N9	0.0341	0.497	0.594	7.401	32.641
N10	0.0114	0.253	0.515	9.748	38.100
Average	0.0197	0.368	0.580	8.412	29.913
Restored Reach					
R1	0.0146	0.402	0.680	6.398	--
R2	0.0121	0.335	0.430	9.275	31.663
R3	0.0120	0.366	0.567	7.806	27.505
R4	0.0125	0.347	0.494	12.890	35.832
R5	0.0178	0.475	0.488	10.918	34.619
R6	0.0107	0.488	0.399	10.132	26.502
R7	0.0033	0.424	0.445	7.839	26.871
R8	0.0079	0.732	0.457	5.660	34.619
R9	0.0487	0.259	0.728	7.053	36.271
R10	0.0092	0.363	0.479	8.632	29.495
Average	0.0125	0.419	0.517	8.660	31.487
Degraded Reach					
D1	0.0013	0.314	0.241	15.496	--
D2	0.1091	0.244	0.960	10.372	38.356
D3	0.0046	0.329	0.351	12.006	29.261
D4	0.0037	0.515	0.448	8.263	27.234
D5	0.0227	0.268	0.689	9.232	27.182
D6	0.0088	0.226	0.442	13.859	27.033
D7	0.0079	0.250	0.372	12.631	31.306
D8	0.0040	0.338	0.396	11.470	28.365
D9	0.0037	0.396	0.360	10.656	21.845
D10	0.0741	0.201	0.951	6.529	29.114
Average	0.0101	0.308	0.521	11.051	28.855

Table 9
Habitat Classifications by RCHARC

Classification	Natural Reach, %	Restored Reach, %	Degraded Reach, %
Undefined	14.1	14.4	17.7
Shallow Pool	35.1	40.5	40.1
Slow Riffle	19.4	15.6	25.8
Fast Riffle	31.0	27.9	16.4
Raceway	0.1	0.9	0.0
Medium Pool	0.3	0.7	0.0
Deep Pool	0.0	0.0	0.0
Total	100.0	100.0	100.0

Table 10
Summary of Depth-Velocity Pairs

Depth, cm	Velocity cm/s	Natural-Percent of Total	Restored-Percent of Total	Degraded-Percent of Total
0	0	11.555	10.791	14.260
0	10	1.164	0.882	0.000
0	20	0.030	0.000	0.946
0	30	0.000	0.182	0.451
0	40	0.149	0.000	0.000
0	50	0.000	0.259	0.766
0	60	0.597	0.000	0.270
0	70	0.000	0.389	0.000
0	80	0.299	0.000	0.338
0	90	0.299	0.000	0.563
0	100	0.000	0.000	0.158
0	120	0.000	0.804	0.000
0	150	0.000	0.052	0.000
0	160	0.000	0.311	0.000
0	200	0.000	0.389	0.000
0	230	0.000	0.389	0.000
10	0	17.522	6.485	4.641
10	10	3.224	10.843	2.816
10	20	0.507	1.427	1.915
10	30	3.284	0.000	1.149

(Sheet 1 of 4)

Table 10 (Continued)				
Depth, cm	Velocity cm/s	Natural-Percent of Total	Restored-Percent of Total	Degraded-Percent of Total
10	40	2.478	1.012	0.360
10	50	1.642	1.608	0.608
10	60	2.866	1.090	0.676
10	70	1.642	2.075	0.000
10	80	2.149	0.182	0.563
10	90	0.896	0.259	0.000
10	100	0.269	0.830	0.135
10	110	0.836	0.234	0.924
10	120	0.030	0.000	0.000
10	130	0.657	0.000	0.563
10	140	0.299	0.000	0.000
10	150	0.179	0.000	0.000
10	160	0.657	1.167	0.000
10	210	0.000	0.908	0.000
10	320	0.000	0.389	0.000
20	-10	0.000	0.545	0.000
20	0	3.134	6.226	3.807
20	10	1.612	3.813	1.081
20	20	2.090	1.427	3.176
20	30	1.194	1.712	2.275
20	40	2.507	2.724	1.329
20	50	1.672	3.009	2.320
20	60	2.478	1.401	2.163
20	70	2.209	2.594	1.352
20	80	0.328	1.660	0.338
20	90	1.791	1.790	1.397
20	100	0.299	0.882	2.005
20	110	1.701	0.052	0.676
20	120	0.299	0.389	0.338
20	130	0.687	0.130	0.315
20	140	0.000	0.389	0.586
20	150	0.090	0.778	0.000
				(Sheet 2 of 4)

Table 10 (Continued)				
Depth, cm	Velocity cm/s	Natural-Percent of Total	Restored-Percent of Total	Degraded-Percent of Total
20	160	0.000	0.000	0.991
20	170	0.567	0.415	0.000
20	180	0.239	0.000	0.000
20	190	0.209	0.000	0.000
20	200	0.030	0.000	0.000
30	0	0.746	1.141	4.551
30	10	2.836	1.634	2.298
30	20	0.478	1.141	2.163
30	30	0.985	0.882	2.974
30	40	0.716	0.208	3.695
30	50	1.701	0.934	3.447
30	60	1.164	2.283	1.622
30	70	0.925	0.441	0.676
30	80	1.433	2.049	0.000
30	90	0.299	0.778	0.000
30	100	0.299	0.804	0.451
30	110	0.000	0.493	0.000
30	120	0.000	0.778	0.000
30	130	0.000	0.000	0.068
30	160	0.000	0.389	0.000
40	-20	0.597	0.000	0.000
40	-10	0.448	0.000	0.000
40	0	0.299	3.165	2.478
40	10	0.000	0.986	2.298
40	20	0.925	0.363	3.199
40	30	0.418	0.908	2.568
40	40	1.134	0.493	2.996
40	50	1.104	1.297	0.586
40	60	0.836	0.130	0.518
40	70	1.075	0.000	0.000
40	80	0.746	0.986	0.000
40	90	0.627	0.000	0.000
				(Sheet 3 of 4)

Table 10 (Continued)				
Depth, cm	Velocity cm/s	Natural-Percent of Total	Restored-Percent of Total	Degraded-Percent of Total
40	100	0.149	0.726	0.000
40	110	0.358	0.000	0.000
50	0	0.418	0.493	0.991
50	10	0.000	0.233	2.906
50	20	0.269	0.545	1.802
50	30	0.000	0.000	0.338
50	40	0.567	0.778	1.126
50	60	0.418	0.000	0.000
50	70	0.657	0.000	0.000
50	80	0.299	0.000	0.000
50	90	0.000	0.078	0.000
50	100	0.299	0.000	0.000
50	120	0.000	0.389	0.000
60	0	0.149	0.000	0.000
60	20	0.149	0.389	0.000
60	50	0.119	0.000	0.000
60	90	0.000	0.156	0.000
70	30	0.000	0.311	0.000
70	60	0.000	0.389	0.000
80	10	0.000	0.337	0.000
				(Sheet 4 of 4)

Discussion of Results

The first output of the RCHARC program for comparing two reaches was the habitat classifications. Each of the reaches displayed similar results (± 5 percent) in the habitat classifications of "undefined," "raceway," "medium pool," and "deep pool." The three comparison reaches varied ± 15 percent in the remaining habitat classifications of "shallow pool," "slow riffle," and "fast riffle." The natural reach exhibited the highest percentage of the "fast riffle" habitat and the lowest percentage in the "shallow pool" habitat. The restored reach displayed the highest percentage of the three reaches in the "shallow pool" habitat and the lowest percentage in the "slow riffle" habitat. The degraded reach exhibited the highest percentage of the three reaches in the "slow riffle" habitat and the lowest in the "fast riffle" habitat category.

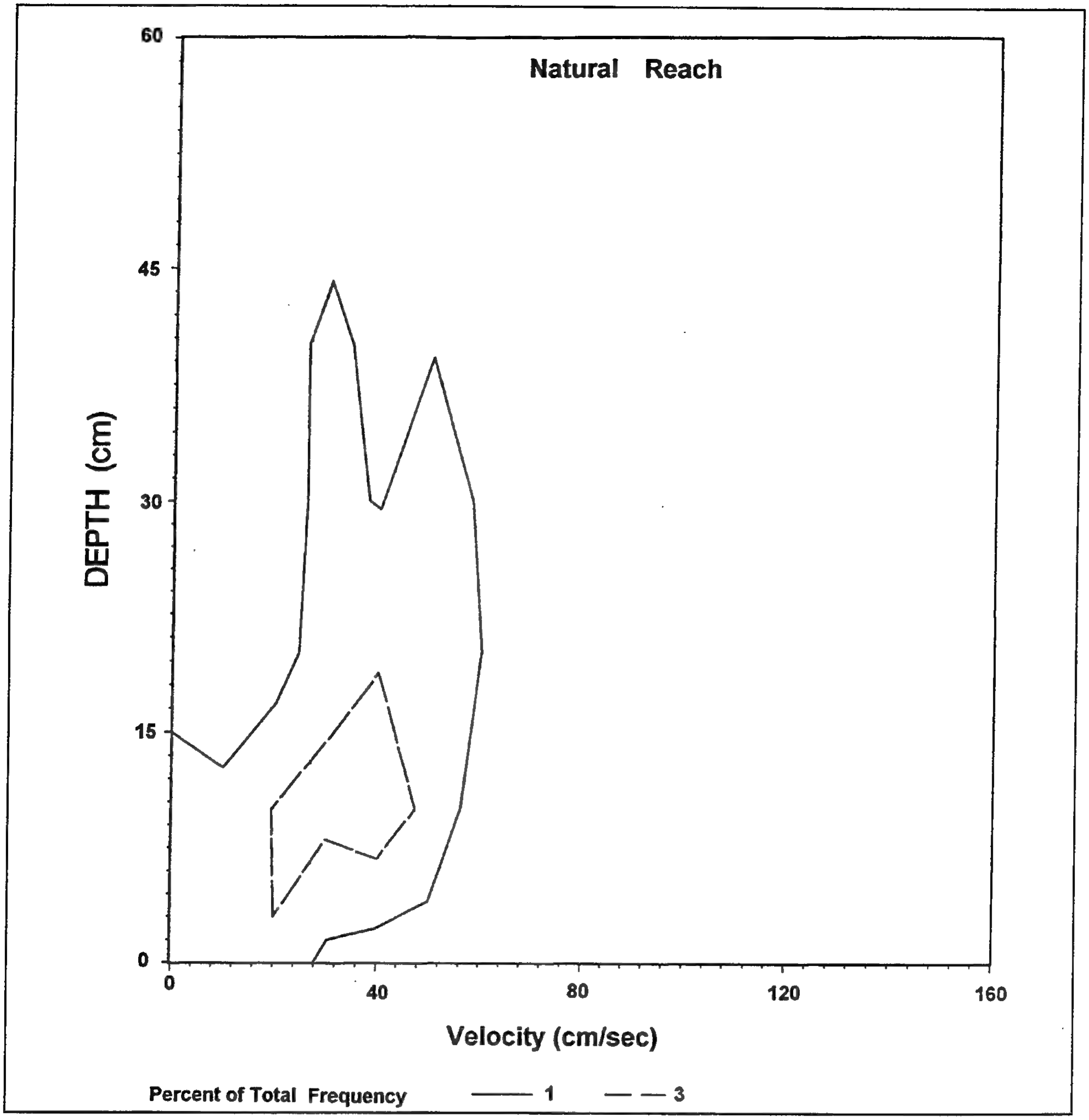

Figure 19. Natural reach—2-D topo-plot produced by RCHARC

The two-dimensional topo-plots reveal that the flow depths and velocities span the quadrant marked by a velocity of approximately 0.6 m/s (60 cm/s) and a depth of approximately 0.45 m (45 cm) for the natural reach; the restored reach spanned to a velocity of approximately 0.95 m/s (95 cm/s) and a depth of approximately 0.55 (55 cm); and a velocity of approximately 0.9 m/s (90 cm/s) and a depth of 0.5 m (50 cm) bounded the plot for the degraded reach. The peak of the distribution for the natural reach is located at approximately 0.4 m/s and 0.1 m; the restored reach peaked at

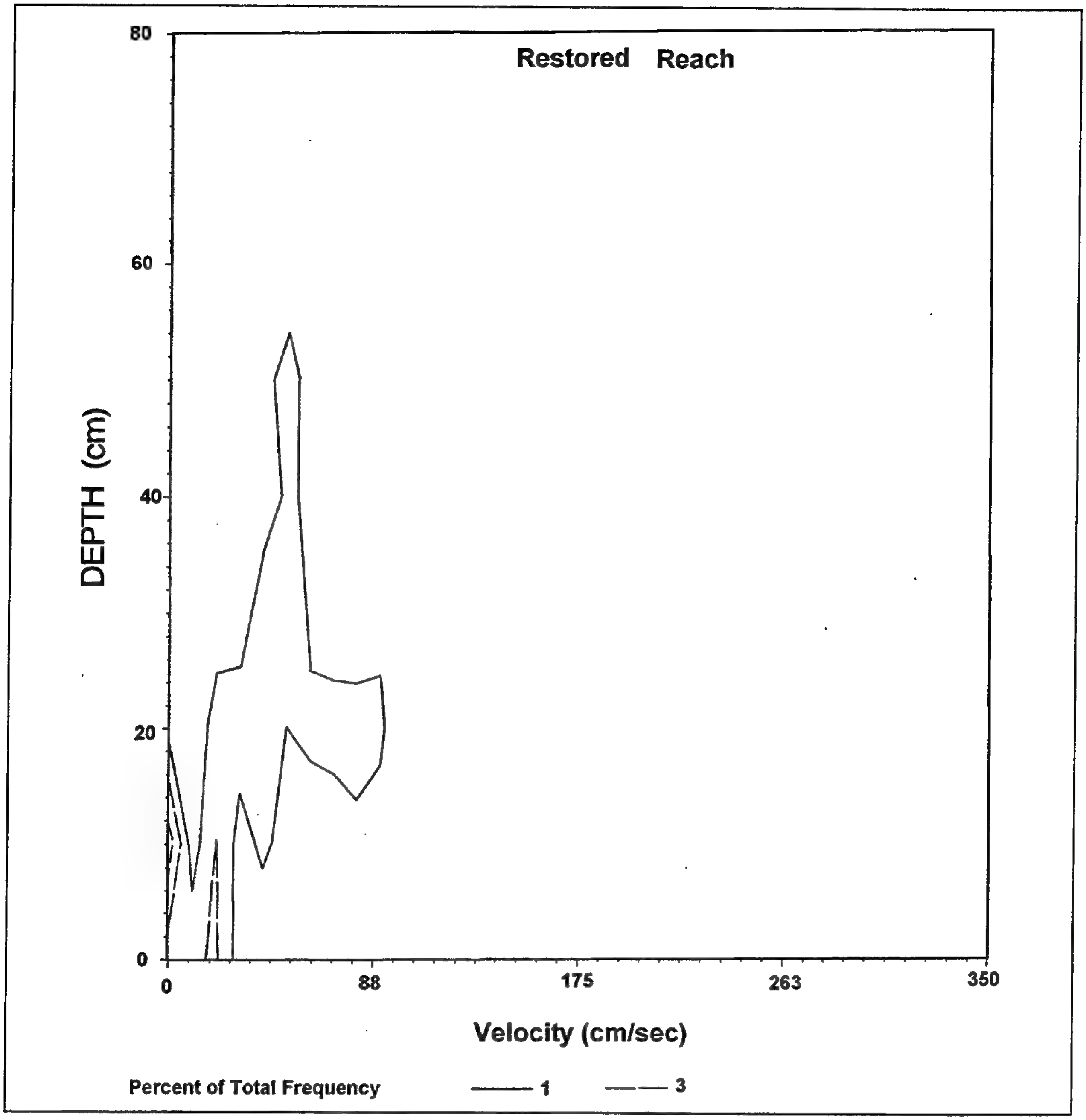

Figure 20. Restored reach—2-D topo-plot produced by RCHARC

approximately 0.2 m/s and 0.6 m; and the degraded reach peaked at approximately 0.25 m/s and 0.2 m. Both the natural and restored reaches exhibit a large percentage of the depth-velocity pairs at shallow depths (depths <0.6 m) and slow velocities (velocities <0.8 m/s). The degraded reach displays a uniform depth-velocity pair distribution over the quadrant.

The generated three-dimensional bivariate surfaces display a more comprehensive view of the depth-velocity pair distributions than the two-dimensional

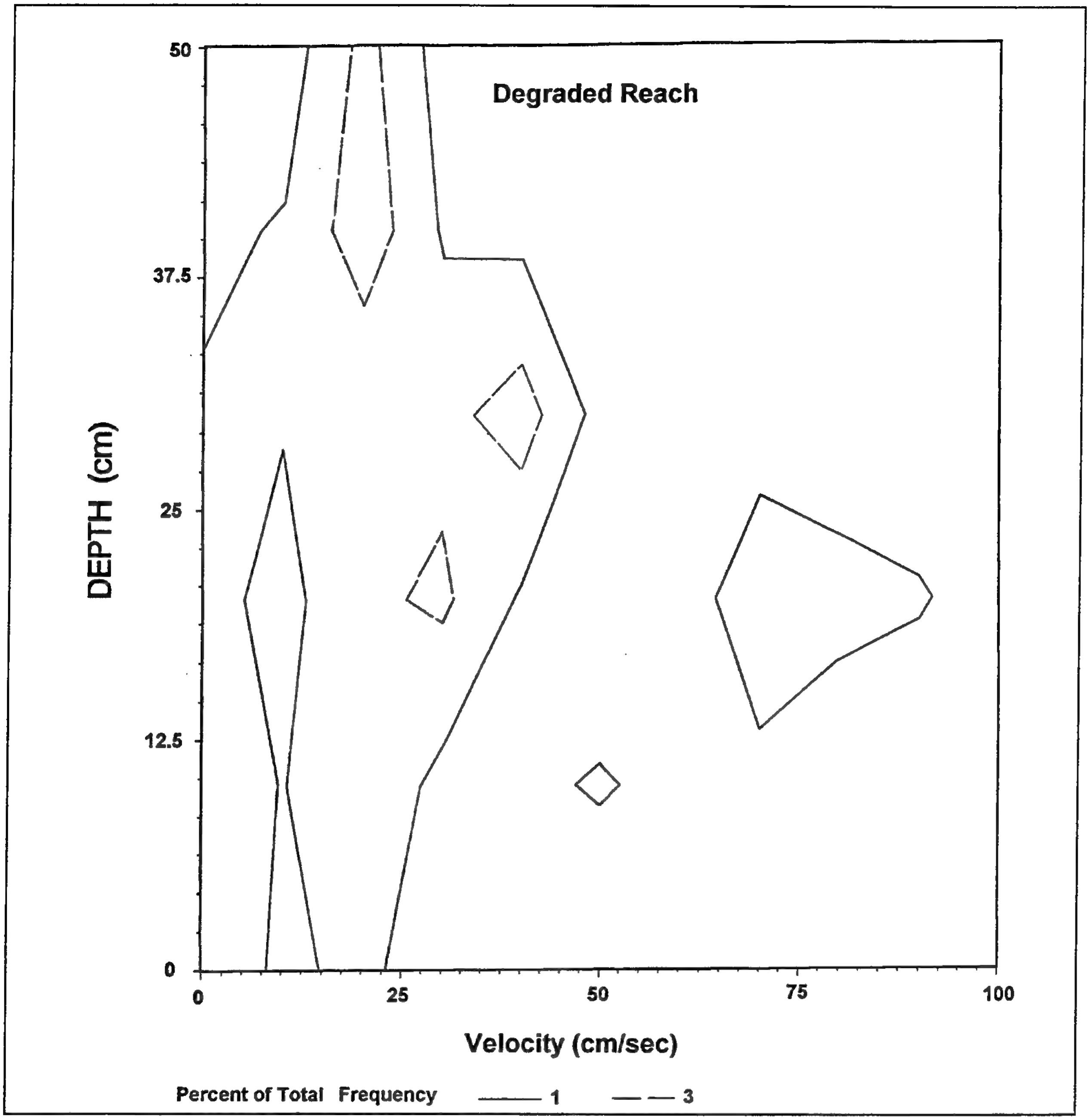

Figure 21. Degraded reach—2-D topo-plot produced by RCHARC

topo-plots. It is observed that a qualitative analysis can be more easily performed to predict the peak distribution for each reach since the surface of the distribution can be observed, whereas the two-dimensional topo-plot only reveals the values of the distribution at specified intervals. The peak of the depth-velocity pair distribution for the natural, restored, and degraded reach was located at 0.1 m and 0.3 m/s, 0.15 m and 0.4 m/s, and 0.2 m and 0.2 m/s, respectively. The three-dimensional bivariate surfaces allow visualization of the uniform depth-velocity pair distribution of the degraded reach

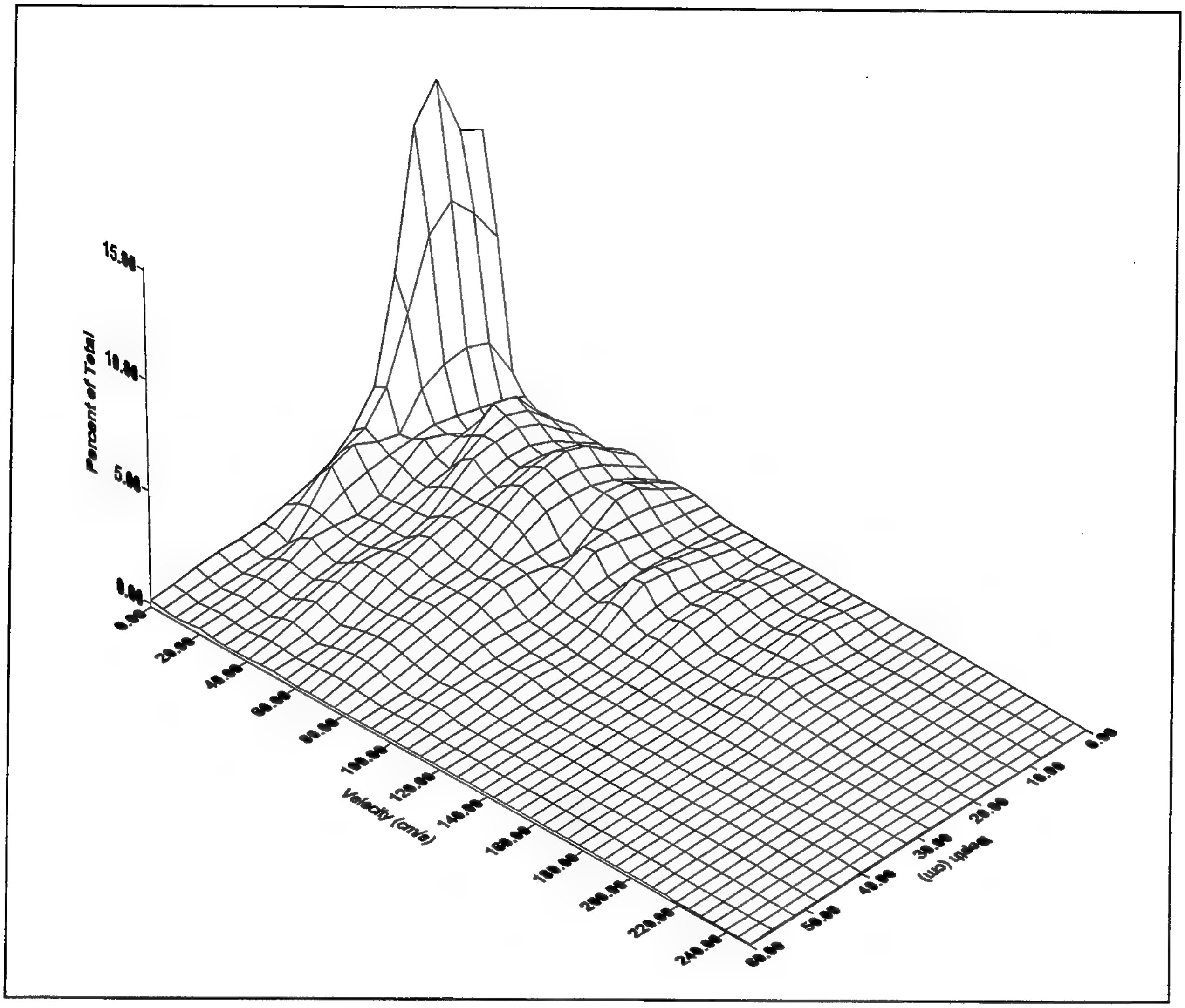

Figure 22. Natural reach—generated 3-D bivariate plot

and the skewed distribution of depth-velocity pairs displayed by the natural and restored reaches.

The RCHARC program computes a Canberra metric coefficient for the comparison reaches. It is observed that the natural and degraded reaches are most similar. When the restored reach was compared with the degraded reach, it was determined that the reaches were the most dissimilar. A Canberra metric coefficient of 0.7 or less indicates a reasonable degree of similarity in comparison alternatives. Therefore, the corresponding similarity coefficient of 0.3 or more indicates a reasonable degree of similarity for the comparison alternatives. The coefficients computed by the RCHARC program for each of the three combinations of comparison alternatives indicate that the reaches do not display a strong degree of similarity.

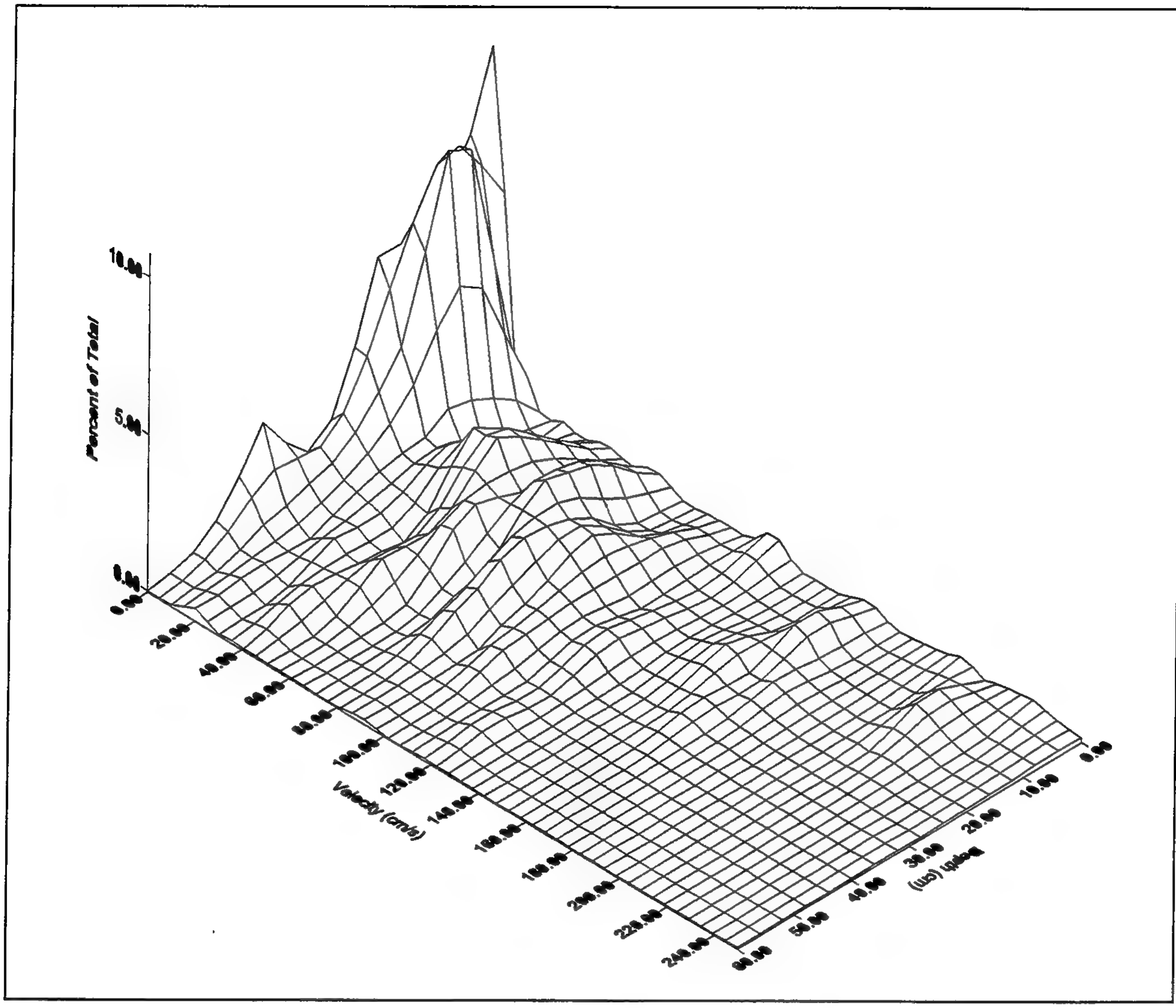

Figure 23. Restored reach—generated 3-D bivariate plot

Recommended Modification of RCHARC

The Goose Creek test demonstrates that the RCHARC process is a viable method to compare aquatic habitats in streams. However, it was also concluded on the basis of the test that the process could be enhanced by amending the program. Among the findings were the following:

a. It was discovered that the SAS program in RCHARC records and analyzes empty depth-velocity pairs. When reaches are compared, one of the empty sets is replaced by a small value (usually two orders of magnitude less than the smallest percentage observed in the depth-velocity pairs) to better describe the difference between the two reaches as discussed in Chapter 2. Because of the manner in which the Canberra metric coefficient is computed, the substitution of the small

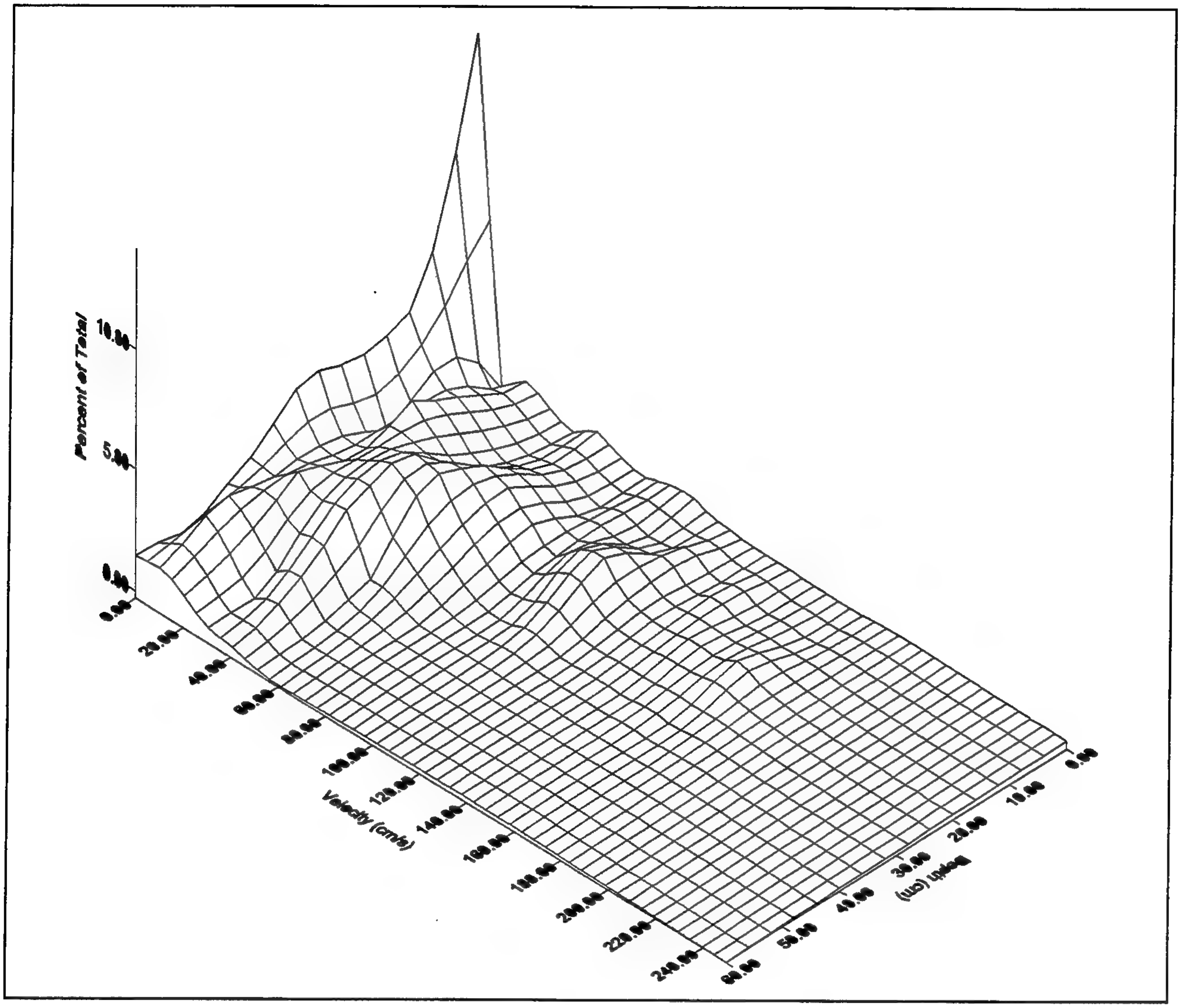

Figure 24. Degraded reach—generated 3-D bivariate plot

Table 11 **Dissimilarity and Similarity Coefficients Computed by RCHARC**			
	Natural Versus Restored	**Natural Versus Degraded**	**Restored Versus Degraded**
Canberra Metric Coefficient, a Measure of Dissimilarity	0.84975	0.80960	0.86416
Coefficient for Similarity	0.15025	0.19040	0.13584

value, when compared with the empty set in the other reach, results in a perfect dissimilarity. This process is described by the following example:

(1) Empty depth-velocity sets retained by SAS.

Depth cm	Velocity cm/s	Reach 1 Percent of Total	Reach 2 Percent of Total
10	170	0.000	0.000

(2) Replacement of one empty set for comparative purposes.

Depth cm	Velocity cm/s	Reach 1 Percent of Total	Reach 2 Percent of Total
10	170	0.000	0.001

(3) The dissimilarity for the empty set is then computed and the result is unity.

Empty sets comprised 56 percent of the recorded data in the natural versus restored comparison, 46 percent of the recorded data for the natural versus degraded comparison, and 58 percent of the recorded data in the restored versus degraded comparison. The presence of recorded empty sets inflates the dissimilarity coefficient for the reaches being compared.

b. The RCHARC program can be written in a computer language more common to engineers, biologists, and scientists (i.e., members of the design team). The user of the RCHARC program must be familiar with the SAS language to operate the program. Since many members in a design team may not be familiar with SAS, the user must become familiar with the SAS language before the RCHARC program can be utilized. To facilitate the acceptance of RCHARC as a standard design tool to engineers, biologists, and scientists, it is recommended that the program be written in a stand-alone, executable code.

c. It is recommended that the IFG4 subprogram be excluded from the RCHARC methodolgy when field data are available. The IFG4 subprogram is included in the RCHARC process to produce simulated depth-velocity pairs. However, it is not necessary to simulate depth-velocity pairs when field depth-velocity pairs are available. The field-collected depth-velocity pairs will yield a more accurate comparison of similarity between reaches than will artificially generated values.

d. RCHARC compares only two of the four variables included in the component of microhabitat (depth and velocity). The complex nature of determining and quantifying cover and its relation to the hydraulics of the stream discourages the use of cover in determining the similarity between reaches. However, it is recommended that a comparison of bed material be included in the method to better assess the similarity of aquatic habitats. Thus, the RCHARC procedure should evaluate three of the four primary microhabitat parameters rather than just two.

5 Enhancement of the RCHARC Program

The RCHARC enhancements described in Chapter 4 were formulated and incorporated into a modified RCHARC program. The modified RCHARC program was developed to be a stand-alone, executable program in a spreadsheet format to facilitate a user-friendly workspace. The modifications to the RCHARC process and program are described to streamline the concept when field data are available. A graphical representation of the modified RCHARC process is presented in Figure 25.

Modified RCHARC Process

The modified RCHARC process begins with the selection of the study reaches as described in Chapter 3. The data collected from the study reaches are segmented for input into the modified RCHARC program and the macrohabitat data compared to ensure the reaches have similar macrohabitats as described in Chapter 4. The modified RCHARC process can then be used to determine the degree of similarity between the study reaches based on the microhabitat components of each reach.

The field-collected data (cross-sectional geometry, flow rates, and assumed Manning's n values) for each reach are input into the HEC-2 program for a flood-capacity analysis. The HEC-2 program is initialized, and the water surface elevations are calculated by the program. The computed water surface elevations are compared with the field-observed water surface elevations. The assumed Manning's n value(s) are then adjusted until the calculated water surface elevations are similar (± 0.07 m) to the observed water surface elevations.

The observed depths, velocities, bed material gradations, and discharges are input, along with the calculated water surface elevations, stream lengths, and widths of the depth-velocity cells, into the modified RCHARC program. The modified RCHARC program is initialized, and the program reorganizes and manipulates the input to produce four sets of output: (a) habitat classifications described by Aadland (1993); (b) a table of the depth-velocity pairs

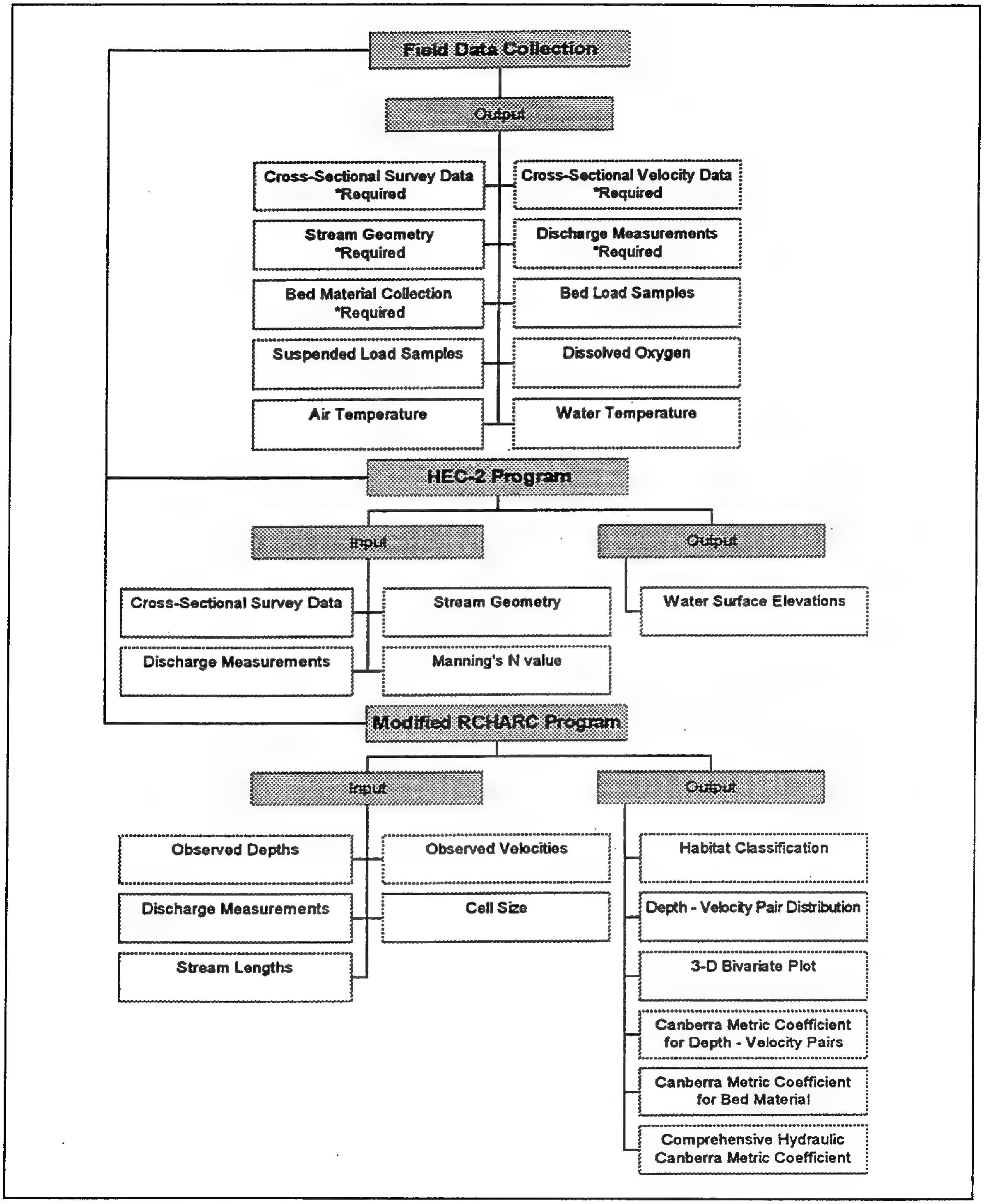

Figure 25. Modified RCHARC process

distribution; (c) a three-dimensional bivariate plot of the depth-velocity pair distribution; and (d) Canberra metric coefficients for depth-velocity pairs, bed material, and the comprehensive hydraulic characteristics of the stream.

Modified RCHARC Program

The modified RCHARC program was formulated in Visual Baler (Baler Software Co. 1994), a commercially available spreadsheet-based program. The spreadsheet format makes it possible to visually inspect the manipulations performed by the program and delete the empty depth-velocity sets. The modified RCHARC process parallels the RCHARC process discussed in Chapter 4 until the HEC-2 output and field data are input into the IFG4 subprogram. Instead, IFG4 is bypassed, and the data are directly input into the modified RCHARC program. The modified RCHARC program then calculates a Canberra metric coefficient for the depth-velocity pairs for the comparison reaches. The modified RCHARC program also calculates a Canberra metric coefficient for the bed material gradations and the comprehensive hydraulic characteristics (depth, velocity, and bed material) of the comparison reaches.

Milhous, Updike, and Schneider (1989) suggest that the depth and velocity portion of the aquatic habitat evaluation process contributes two-thirds of the total microhabitat assessment. The remaining variables (i.e., armor layer gradation, cover, etc.) comprise one-third of the total microhabitat assessment. Therefore, the comprehensive hydraulic coefficient in the modified RCHARC program weights the depth-velocity pair component of the Canberra metric coefficient by two-thirds. Cover is not directly related to the hydraulic characteristics of the stream. However, the substrate is influenced by the hydraulic conditions existing in the stream. Since RCHARC was designed to compare stream hydraulic parameters, cover was not considered. The Canberra metric coefficient for the bed material is assigned a weight of one-third.

The spreadsheet program is equipped with a graphics package and plots a three-dimensional depth-velocity bivariate surface plot of the data obtained from each reach. The graphics package was not intended for scientific plotting of data. Therefore, the output graphics are only to visualize the trends of the depth-velocity pair distribution.

Results From Modified RCHARC Program

The database reported in Chapters 3 and 4 is used for the evaluation of the modified RCHARC program. Therefore, the results from the HEC-2 analysis are synonymous to the results in Chapter 4. The data are then input into the modified RCHARC program and initialized. The program organizes the data and calculates the total percent of each reach's habitat into habitat classifications described by Aadland (1993). The tables for the habitat

classifications for natural (CSRS), restored, and degraded reaches are presented in Table 12.

Table 12
Habitat Classifications Computed by Modified Program

Classification	Natural Reach, %	Restored Reach, %	Degraded Reach, %
Undefined	11.1	16.1	8.1
Shallow Pool	33.5	30.1	35.3
Slow Riffle	27.4	25.9	37.3
Fast Riffle	27.4	25.2	17.2
Raceway	0.4	0.5	0.7
Medium Pool	0.1	2.2	1.6
Deep Pool	0.0	0.0	0.0
Total	100	100	100

The classified habitats for each of the comparison reaches are compared. All three reaches compared are within ±5 percent in the classified habitat of "shallow pool," "raceway," "medium pool," and "deep pool." Of the remaining classified habitats, the natural reach exhibits the highest percentage of the three reaches in the "fast riffle" category but the lowest percentage in the "slow riffle" category. The restored reach exhibits the highest percentage of the three reaches in the undefined habitat classification. The highest percentage in the "slow riffle" category was exhibited by the degraded reach, while the degraded reach exhibited the lowest percentage in the categories of "fast riffle" and the undefined habitat. The results of the dissimilarity and similarity coefficients for the three comparison combinations are presented in Table 13. The natural reach versus restored reach comparison exhibits the lowest Canberra metric coefficient (dissimilarity) for depth-velocity pairs, 0.55007, which corresponds to the greatest degree of habitat similarity. The greatest degree of habitat dissimilarity among the three comparison combinations for depth-velocity pairs is 0.58840 resulting from the comparison of the natural and degraded reaches. All reaches demonstrate a good degree of habitat similarity for depth-velocity pairs since Canberra metric coefficients (dissimilarity) of 0.7 and below constitute a good degree of habitat similarity.

The Canberra metric coefficients for the armor layer and substrate reveal that the restored reach and the degraded reach have similar bed material gradations with a dissimilarity coefficient of 0.1570. It is also observed that the natural reach and the degraded reach have the least similar bed material with a dissimilarity coefficient of 0.49284. However, the comparisons indicate all reaches have a good degree of similarity for bed material.

Table 13
Dissimilarity and Similarity Coefficients Computed by Modified Program

Natural Versus Restored	
Canberra Metric Coefficient for Depth-Velocity	
Canberra Metric Coefficient	0.55007
Coefficient of Similarity	0.44993
Canberra Metric Coefficient for Substrate and Armor Layer	
Canberra Metric Coefficient	0.45757
Coefficient of Similarity	0.54243
Comprehensive Hydraulic Canberra Metric Coefficient	
Canberra Metric Coefficient	0.51934
Coefficient of Similarity	0.48066
Restored Versus Degraded	
Canberra Metric Coefficient for Depth-Velocity	
Canberra Metric Coefficient	0.5878
Coefficient of Similarity	0.4122
Canberra Metric Coefficient for Substrate and Armor Layer	
Canberra Metric Coefficient	0.1570
Coefficient of Similarity	0.8429
Comprehensive Hydraulic Canberra Metric Coefficient	
Canberra Metric Coefficient	0.4442
Coefficient of Similarity	0.5557
Natural Versus Degraded	
Canberra Metric Coefficient for Depth-Velocity	
Canberra Metric Coefficient	0.58840
Coefficient of Similarity	0.41160
Canberra Metric Coefficient for Substrate and Armor Layer	
Canberra Metric Coefficient	0.49284
Coefficient of Similarity	0.50716
Comprehensive Hydraulic Canberra Metric Coefficient	
Canberra Metric Coefficient	0.55655
Coefficient of Similarity	0.44345

The comprehensive hydraulic Canberra metric coefficient indicates that the restored reach and the degraded reach are the most similar of the three comparison combinations with a dissimilarity coefficient of 0.4442. The natural reach and the degraded reach are the least similar with a dissimilarity coefficient of 0.55655. All reaches exhibit a good degree of similarity for the comprehensive hydraulic characteristics of the stream.

The modified program then generates the three-dimensional depth-velocity pair bivariate plots for the comparison reaches. The bivariate surface plots for the natural (CSRS), restored, and degraded reaches are presented as Figures 26, 27, and 28, respectively.

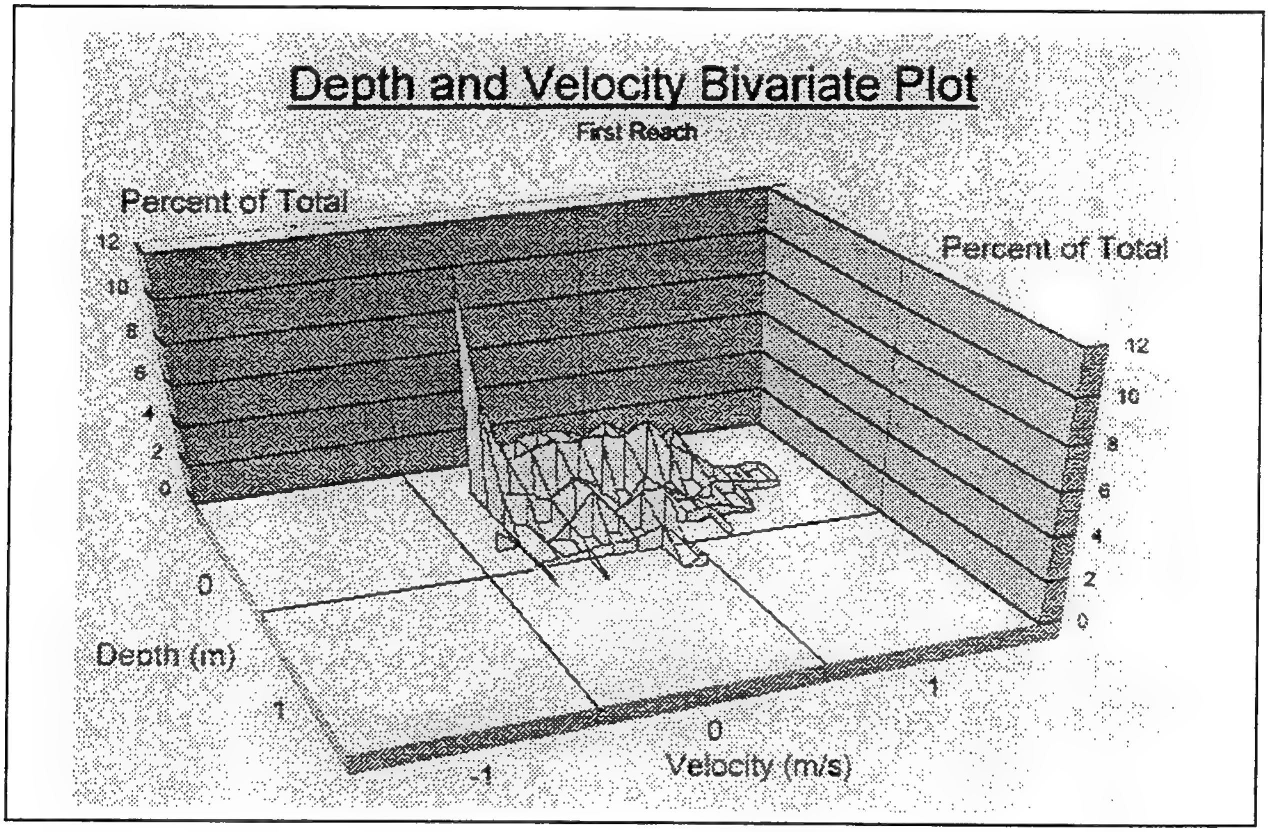

Figure 26. A 3-D plot generated by modified program—natural reach

The natural and restored reaches display a trend for low depth (depth < 0.8 m) and low velocity (velocity < 0.8 m/s) pairs. The surfaces for the natural and the restored reaches skew toward the origin (0 cm of flow depth and 0 m/s of flow velocity). The degraded reach displays a uniform depth-velocity pair distribution and is not skewed toward the origin.

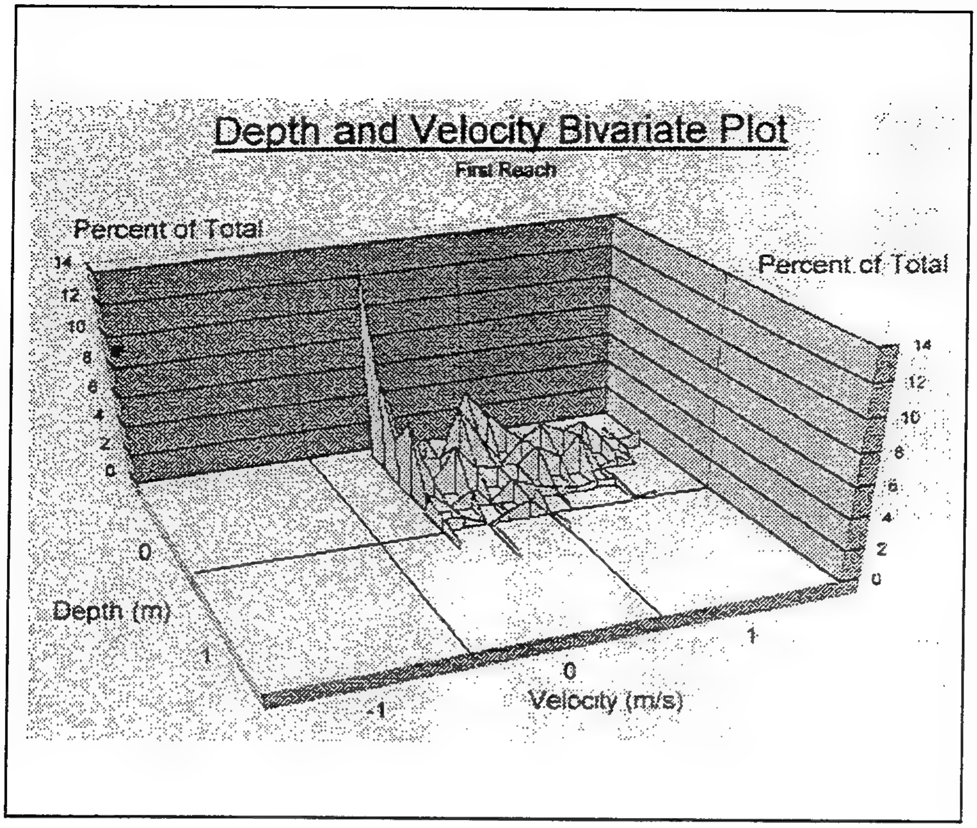

Figure 27. A 3-D plot generated by modified program—restored reach

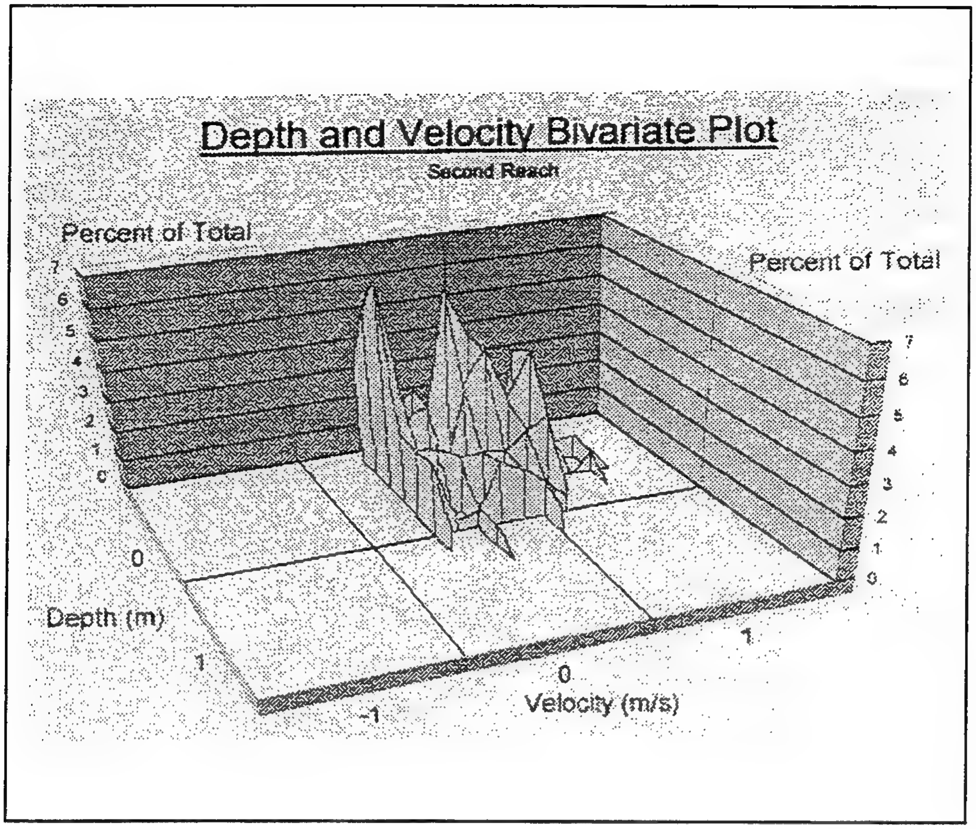

Figure 28. A 3-D plot generated by modified program—degraded reach

6 RCHARC and Modified RCHARC Comparison

The microhabitat data from Goose Creek, Colorado, was input into the RCHARC program (Chapter 4) and the modified RCHARC program (Chapter 5). The habitat classifications and Canberra metric coefficients for three comparison combinations as well as graphic representations of the depth-velocity pair distributions are presented. The modified RCHARC program was written to be user friendly, remove empty depth-velocity pairs, bypass the IFG4 subprogram, and quantitatively incorporate bed material gradations into the similarity analysis. A comprehensive hydraulic Canberra metric coefficient is computed based on the depth-velocity pairs and the bed material.

Comparisons of Classified Habitats

A comparison of the RCHARC program output and the modified RCHARC program output for the habitat classifications is presented for the natural reach, restored reach, and degraded reach in Tables 14-16, respectively. The two programs produced similar results. The root mean square of the difference in percentage of classified habitat calculated by the two programs is ±3.573, ±5.701, and ±6.023 percent for the natural reach, restored reach, and the degraded reach, respectively.

Table 14
Habitat Classification Differences—Natural Reach

Classification	Modified RCHARC, %	Current RCHARC, %	Difference in Percentage, %
Undefined	11.124	14.092	2.968
Shallow Pool	33.533	35.103	1.570
Slow Riffle	27.450	19.402	-8.048
Fast Riffle	27.352	30.984	3.632
Raceway	0.405	0.119	-0.286
Medium Pool	0.137	0.298	0.161
Deep Pool	0.000	0.000	0.000

Table 15 Habitat Classification Differences—Restored Reach			
Classification	Modified RCHARC, %	Current RCHARC, %	Difference in Percentage, %
Undefined	16.082	14.449	-1.633
Shallow Pool	30.059	40.467	10.408
Slow Riffle	25.898	15.564	-10.334
Fast Riffle	25.238	27.938	2.700
Raceway	0.486	0.856	0.370
Medium Pool	2.238	0.726	-1.512
Deep Pool	0.000	0.000	0.000

Table 16 Habitat Classification Differences—Degraded Reach			
Classification	Modified RCHARC, %	Current RCHARC, %	Difference in Percentage, %
Undefined	8.051	17.752	9.701
Shallow Pool	35.255	40.122	4.867
Slow Riffle	37.288	25.772	-11.516
Fast Riffle	17.173	16.355	-0.818
Raceway	0.676	0.000	-0.676
Medium Pool	1.557	0.000	-1.557
Deep Pool	0.000	0.000	0.000

The removal of the IFG4 subprogram from the RCHARC program has little effect on the results as exemplified by the relatively small change between the percentage of classified habitats. The RCHARC program uses the simulated depth-velocity pairs calculated by the IFG4 subprogram, while the modified RCHARC program uses the field-collected depth-velocity pairs. The largest absolute difference of percentages between any of the comparison reaches is 11 percent. The root mean square of the differences of percentages for all reaches compared is approximately 5 percent.

Comparison of Canberra Metric Coefficients

Each program calculates a Canberra metric coefficient for the three comparison combinations. The RCHARC program produces inflated dissimilarity coefficients since it records and analyzes empty depth-velocity pairs. The empty depth-velocity pairs are not recorded by the modified RCHARC program. Therefore, the two programs produced drastically different results. The RCHARC program results indicate that the comparative reaches have

little similarity as the lowest Canberra metric coefficient (lowest degree of dissimilarity) is 0.80960 (natural versus degraded). The Canberra metric coefficients computed by the RCHARC program exceed 0.7. A value of 0.7 or less is indicative of a reasonable degree of similarity between the comparison reaches.

The results of the modified RCHARC program indicate that the comparison reaches are more similar than the results of the RCHARC program. The highest Canberra metric coefficient (highest degree of dissimilarity) for the depth-velocity pairs is 0.58840 (natural versus degraded), while the highest comprehensive hydraulic Canberra metric coefficient (highest degree of dissimilarity) is 0.55655 (natural versus degraded). The highest degree of similarity derived from the RCHARC program (natural versus degraded) displays the lowest degree of similarity of the three comparisons by the modified RCHARC program.

The depth-velocity pairs input into the RCHARC program were adjusted to remove the empty depth-velocity pairs. The highest Canberra coefficient (highest degree of dissimilarity) from the adjusted data set is 0.67303 (restored versus degraded). Tables 17-19 present the Canberra metric coefficients for all three comparison reaches of Goose Creek for the RCHARC program with original data (RCHARC), the RCHARC program with adjusted data (Data-Corrected RCHARC), and the modified RCHARC program.

Table 17
Canberra Metric Coefficients—Natural Versus Restored

	RCHARC	Data-Corrected RCHARC	Modified RCHARC (depth and velocity)	Modified RCHARC (comprehensive hydraulic)
Canberra Metric Coefficient	0.84975	0.65742	0.55023	0.51934
Similarity Coefficient	0.15025	0.34258	0.44977	0.48066

Table 18
Canberra Metric Coefficients—Natural Versus Degraded

	RCHARC	Data-Corrected RCHARC	Modified RCHARC (depth and velocity)	Modified RCHARC (comprehensive hydraulic)
Canberra Metric Coefficient	0.80960	0.64355	0.58827	0.55646
Similarity Coefficient	0.19040	0.35645	0.41173	0.44354

Table 19
Canberra Metric Coefficients—Restored Versus Degraded

	RCHARC	Data-Corrected RCHARC	Modified RCHARC (depth and velocity)	Modified RCHARC (comprehensive hydraulic)
Canberra Metric Coefficient	0.86416	0.67303	0.58780	0.44421
Similarity Coefficient	0.13584	0.32697	0.41220	0.55579

A comparison of the Canberra metric coefficients derived from the RCHARC program and the Canberra metric coefficients derived from the modified RCHARC program indicate two significantly different reach comparisons. However, when the empty sets are hand removed from the data (Data-Corrected RCHARC), the RCHARC program produces a Canberra metric coefficient similar (±0.1) to those computed by the modified RCHARC program. The largest difference between these two coefficients (Data-Corrected RCHARC and the modified RCHARC program for depth-velocity pairs) is approximately 0.107. This indicates that the two programs produce similar Canberra metric coefficients for depth-velocity pairs when the empty sets are removed from the input data before input into the RCHARC program.

A comparison of the bed material gradations (armor layer and substrate) of the comparison reaches is performed by calculating a Canberra metric coefficient. The results indicate that the bed material comparison is not a major factor in determining the degree of similarity between reaches. Observing the natural versus restored and the natural versus degraded comparisons, the Canberra metric coefficients for depth-velocity pairs closely compare (±0.03) to the coefficients determined for the comprehensive hydraulics of the stream.

A bed material comparison may be a decisive factor in selecting a restoration design alternative. A comparison of the restored versus degraded reaches is the least similar of the three comparisons based only on depth-velocity pairs. The bed material of the restored reach and the degraded reach displays high degree of similarity and when incorporated into the comprehensive hydraulic Canberra metric coefficient, indicates that the restored versus degraded comparison is the most similar of the three comparison reach combinations. The bed material comparison more completely describes the effectiveness of a restoration design alternative when combined with depth-velocity pair comparisons.

It is observed that the three comparison combinations produced relatively similar (±0.04) Canberra metric coefficients when comparing only depth-velocity pairs. When the bed material gradations are included in the comprehensive hydraulic Canberra metric coefficient, the difference between the comparison combinations was broadened (± 0.11). By including the bed

material comparison into the Canberra metric coefficient, the diversity that exists between the comparison reaches was revealed.

Comparison of Depth-Velocity Plots

The depth-velocity pair distribution plots produced by both programs is relatively similar. The modified RCHARC program produces bivariate plots that are more skewed toward the origin than the RCHARC program. The RCHARC program produces a topo-plot that connects equal elevations in the depth-velocity pair distribution. The distribution of the depth-velocity pairs between the contour lines is unknown. A sample plot from the RCHARC program and the modified RCHARC program is presented in Figures 29 and 30, respectively.

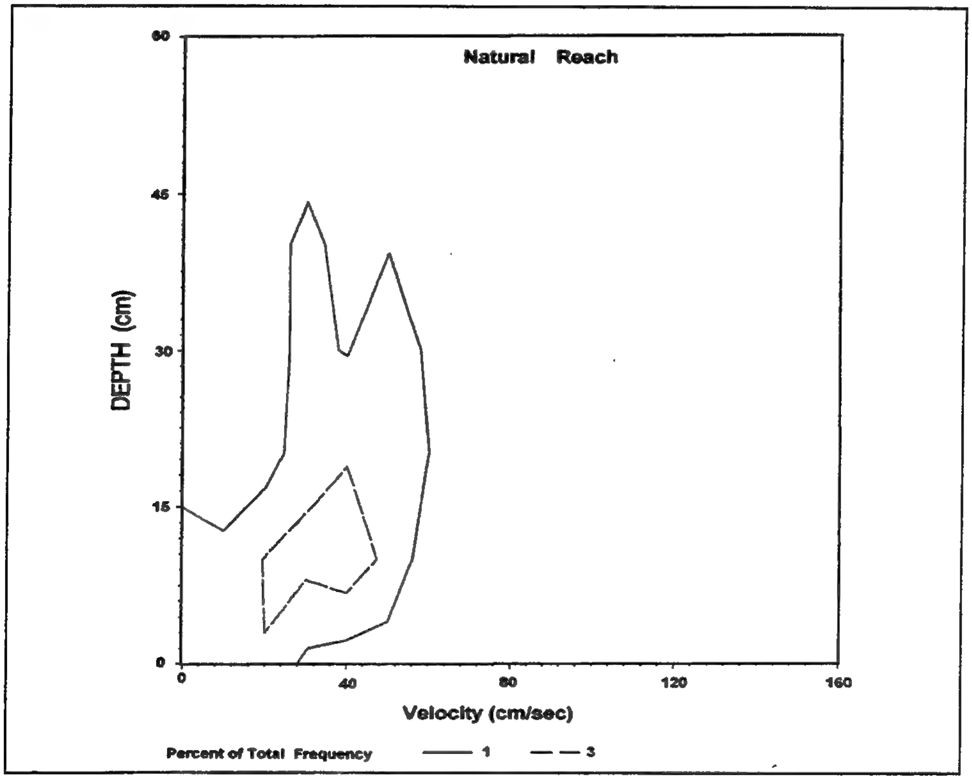

Figure 29. Topo-plot produced by RCHARC program

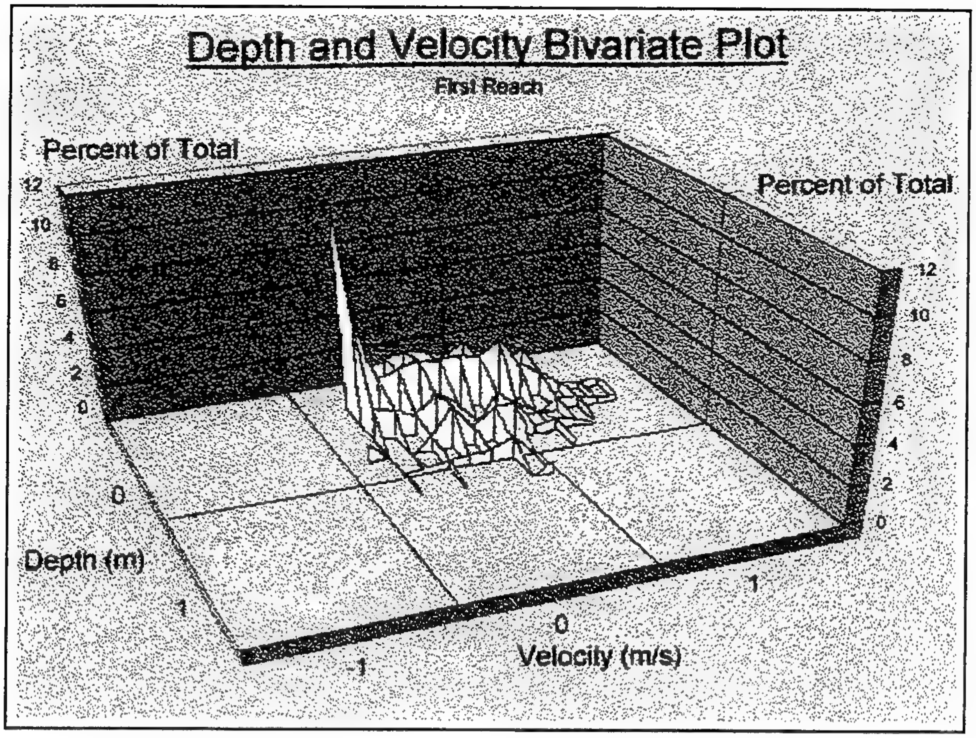

Figure 30. A 3-D bivariate plot produced by modified RCHARC program

7 Conclusions and Recommendations

The results from the RCHARC analysis are presented in Chapter 4. The modified RCHARC program was modified per the recommendations presented in Chapter 4 and modified RCHARC program was beta tested as detailed in Chapter 5, using the same field database. The outputs from the two programs were compared in the preceding chapter. Conclusions and recommendations from the comparison and analyses follow.

Conclusions

- The RCHARC methodology is a viable means to assess aquatic habitat similarity between comparison reaches.

- A complete design process that includes the implementation of RCHARC to analyze an aquatic habitat analysis into the channel restoration process.

- The RCHARC program can be enhanced by the following:

  a. Eliminating empty depth-velocity pairs from the analysis.

  b. Writing a stand-alone, executable code more easily used by scientists and engineers (the design team).

  c. Bypassing the IFG4 subprogram when field-collected data are input into the RCHARC program.

  d. Incorporating bed material gradations into the evaluation process.

- The Canberra metric coefficient obtained by the modified RCHARC gives a better comparison of the reaches than does the coefficient from the unmodified version since more hydraulic characteristics are considered and empty depth-velocity sets are removed.

- Qualitative analysis of the depth-velocity pair distribution is enhanced over the 2-D contour plots by using 3-D bivariate plots that describe the entire depth-velocity pair surface.

- The removal of the IFG4 subprogram has little or no effect on the assessment of aquatic habitat.

Recommendations

- The recommended enhancements of the RCHARC program detailed in Chapter 4 should be implemented.

- Flume and/or field studies should be conducted to determine the effects that hydraulic structures (boulder clusters, spur dikes, boulder-lined bank, etc.) have on stream habitat. Predictive techniques for the impacts of these structures are necessary when applying RCHARC to the planning and design of new restoration projects.

- The RCHARC (or modified RCHARC) design process, described in Chapters 3, 4, and 5, needs to be applied in a field design and construction situation for a more complete evaluation.

- A quantitative coefficient, other than the Canberra metric coefficient, should be developed and incorporated into the RCHARC program.

- Means of incorporating the fourth microhabitat variable, cover, into the analysis should be investigated.

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Appendix A
Cross-Section Descriptions

A qualitative description of each cross section in each of the three reaches was adapted from written observations taken in the field. For reference, Figures 6 and 7 in the main text show the locations of the cross sections described below.

Natural Cross-Section Descriptions

Natural section #1

A 0.5-m rise from the right water's edge greets the 0.6-m-tall grass and weeds growing out of the right bank. Pine and deciduous trees litter the right overbank. A tree overhangs most of the channel. The right floodplain contains a 9.1-m-tall grove of trees, and behind the trees lies a dry channel where 0.6-m-tall grass has grown among the fallen trees. The dry channel extends to the cliff behind it. Water in the 9.1-m-wide channel flows over 0.3-m-diam and smaller bed material which is rounded and slick with moss. The channel does not contain algae. The left bank is relatively flat for the first 3 m and is composed of dry bed material. Grass grows to a height of 0.61 m between densely grown willows and 1.8-m-tall bushes on the left floodplain.

Natural section #2

Deadwood lines a 0.6-m drop from the right bank to the water's edge. The top of the right bank is covered with 0.3-m grass and young trees. Some rocks on the right bank are exposed. The floodplain on the right is characterized by a couple of rows of tall trees and the dry channel that is also behind the previous section. The water in the channel is extremely narrow and swift. The 4.6-m-wide channel contains 0.3- and 0.6-m-diam rounded stones in 0.6-m-deep water. The left bank begins with an 0.8-m-high grass cliff. Immediately downstream, the left bank is covered with river rock and contains

little to no vegetation. Willows and bushes exist on the left floodplain along with a sprinkling of trees.

Natural section #3

The first 0.61 m of the right bank have been eroded to expose large 0.3- to 0.6-m-diam rocks. A 1-m cliff then rises above the bank. It is topped with trees and 0.5-m-tall weeds growing among driftwood that is stacked against the trees. Two trees overhang the channel. The dry channel on the right floodplain is wider than in the previous two sections and again ends at the cliff. The 6.4-m-wide streambed is a bit wider than the previous section and is located just upstream of a narrow, rapid section of river. The bed material is 0.3-m-diam and smaller river rock. The left bank consists of a 0.6-m cliff that rises from the water's edge. The downstream section of the left bank contains piled up driftwood on top of a rock bar. Grass grows to a height of 0.6 to 1.2 m and extends to the dense brush on the left floodplain.

Natural section #4

The right bank consists of bed material. The right bank in this section is the entrance to the dry channel that runs behind Sections 1, 2, and 3. Driftwood is lined up along the bushes on top of the bank. Just downstream is the beginning of the island that separates the dry channel from the main channel. The top of the island is covered more densely with bushes than in the dry channel. The 7-m-wide channel is dotted with 0.6-m-diam boulders, but the bed material is about 0.15 m in diameter. The left bank is about an 0.8-m grass-covered rise from the water's edge. The bank is eroded at the bottom, and the rocks beneath the soil are exposed. The bushes, trees, and the floodplain are only 0.6 m away from the water's edge.

Natural section #5

An 0.8-m rocky cliff on the right bank is held together with small clumps of 0.3-m-tall weeds. The rocky landscape continues until large brush starts to grow about 30.4 m from the water's edge. The water flowing in the 7.6-m-wide channel runs deep and fast. The bed material is again made up of 0.3-m-diam and smaller river rocks. The left bank has been exposed to much erosion, and a 6.1-m-high tree is about to fall in the channel. Logs overhang the one-to-one rocky left bank. The rocks give way to the forest of willow and bushes on the left floodplain.

Natural section #6

This section is 0.61 m downstream of an old log drop structure. The five to one slope of the right bank is covered with 0.07-m-diam rock. The rocks

on the right bank are larger, and the slope gets steeper further downstream of the cross section. About 4.6 m from the water's edge, mature trees and 0.8-m-tall grass grow. The channel is the pool of the log drop structure, and the section is relatively wide at 9.1 m. The bed material is similar to the previous sections except there are no rocks greater than 0.3 m in diameter. The left bank if lined with driftwood and 0.3-m-diam rock. The bank is 0.8 m high with 0.6-m-tall grass growing from the top of the bank. The left floodplain is only 6.1 m wide because of a rock cliff resting behind the grass.

Natural section #7

The first 3.1 m of the right bank is dry riverbed. The rocks jutting out of the bank are moss covered. Driftwood has stacked against the 1.2-m-high eroded right bank, and the bank is home to 0.5-m-high grass and three groups of trees. The channel bed has 0.2-m-diam bed material. The water ripples due to the 12.2-m span and low-water depth. The left bank is a cliff with 1.2-m-tall bushes growing just upstream of the section.

Natural section #8

About 9.1 m from the right water's edge to the right bank is lined with dry bed material. The right bank is lined with two old logs where the bank slopes upward with little to no ground vegetation. The right bank is covered with trees. The 6.7-m-wide channel flows quickly over similar bed material as previous sections. The left bank begins with a 0.9-m rise with 0.3-m-diam rocks at the bottom and 0.6-m-high bushes at the top. The overbank is a densely vegetated plateau and ends at the bottom of a cliff.

Natural section #9

The right bank is a moss-covered cliff that is home to a few small trees. The water in the channel is forced into the rock cliff on the right side of the channel. The water has eroded the channel bed near the cliff, and the channel is deeper at that point. The channel at this section is 7.6 m wide. The left bank cannot be seen because trees and bushes overhang the water. Past the overhanging trees lie rocks and small ground vegetation.

Natural section #10

Deadwood and a fallen tree line the right bank. A mossy 0.5-m rise yields to 0.3-m-high grass growing on the top of the right bank. The overbank is about 6.1 m wide, tree covered, and ends in a steep ascent up a mountain side. The 9.4-m-wide section is the only characteristic that distinguishes this section from any of the previous sections. The left bank slopes gently away from the water at an eight to one slope. One row of 0.2-m-diam rocks lines

the left bank. Trees and bushes dot the left bank, and not much ground vegetation exists. The bank ends in a steep ascent up a mountain side.

Restored Cross-Section Descriptions

Restored section #1

Logs are tied to the right bank for protection at the water's edge. The rocks that line the two to one slope are 0.3 m in diameter. Small 0.15-m vegetation grows on the 0.9-m-tall right bank. The right floodplain is flat and covered with 0.3-m-tall grass. The streambed is filled with 0.15-m and smaller diameter rock with four 0.6-m-diam boulders mixed in. The 6.7-m-wide channel is also home to groups of algae. The gently sloping left bank is lined with 0.3-m-diam rocks which finally give way to 0.5-m-high grass. The left floodplain is covered by lush 0.5-m-high grass.

Restored section #2

Two 0.6-m-diam rocks rest at the right water's edge among a 1.5-m stretch of fine sand. The right bank's gentle slope gives way to 0.6-m-tall grass on the right floodplain. The wide 9.8-m stream channel runs deep and smooth over 0.15-m bed material. Algae grows among some of the large boulders spaced throughout the channel. The first 0.3 m of the left bank is littered with 0.15-m-diam rocks. Moving up the left bank, a strip of 0.3-m-tall plants grow around a 2.4-m-tall willow. The floodplain on the left side is first covered with rocks which give way to 0.5-m-tall grass.

Restored section #3

The first 6.1 m of the right bank are gently sloping and littered with 0.3-m-diam rocks and small clumps of grass. The right floodplain is relatively flat with 0.5-m-tall grass growing on it. The water runs rapidly in a 7.6-m section. There are only two larger rocks in the stream channel mixed with 0.15-m-diam bed material. The algae in this section is growing near the banks. Trees anchored to the left bank help protect the steep bank from eroding. The left bank is 0.9 m high and armored with 0.2-m-diam rocks. The top of the bank is covered in 0.3-m-high grass. The floodplain consists of rolling grassy hills.

Restored section #4

The right bank at a flow of 0.9 m^3 per second is an island at higher flows. However, it is covered with 0.3-m-diam rock. The 0.6-m-tall weeds on the right bank help hold the rocks together. At high flows, the right bank is steep

and covered with 0.3-m-tall grass. The right floodplain is covered with short 0.15-m-tall grass. The 10.7-m-wide channel holds rapidly flowing water and six rocks that are larger than 0.15-m bed material. In this section of river, no algae grows. The 0.8-m-tall bank yields 0.6-m-tall grass. The left floodplain has low-growing plants and rolling grassy hills.

Restored section #5

The right bank is made up of silt, 0.5-m-tall grass, and 0.07-m-diam rocks. The right bank is 1 m high and gives way to the right floodplain, which is covered with 0.3-m-tall grass. The algae laden 9.6-m-wide stream flows over a drop made of several 1-m-diam rocks formed in the shape of a horseshoe. Large 0.6-m-diam rocks and driftwood line the left bank. A 0.3-m-rise from the left water's edge reveals a dry streambed. The grassy rolling hills of the left floodplain, about 20 m from the water's edge, run to the edge of the mountains.

Restored section #6

The right bank is still a small island, but it is densely packed with willows and bushes. Where there is space, 0.15-m-tall grass grows. About 12.2 m from the water's edge, 1-m-tall bank is coated with 0.3-m-high grass. The water in the 9.8-m-wide channel flows wide and calm. The same 0.15-m bed material exits and is coupled with two larger 0.6-m-diam rocks among groups of algae. Trees are again used to line and protect the left bank near the water's edge. Large 0.6-m-diam rocks rest near the water's edge. An 0.8-m-rise from the water's edge gives way to 0.3-m-tall grass. The grass continues to the left floodplain.

Restored section #7

The right bank is densely packed with bushes and vegetation. Again, the island-like formation exists and extends for 9.1 m from the right water's edge. The water in the 7.9-m-wide channel is forced to the left due to a slope in the bed to the right. This forces the water to flow deeper and faster on the left. There are no large rocks in the channel, and algae grows only on the left side of the channel. The log-lined left bank is 0.9 m high and covered with 0.5-m-diam rocks. The left floodplain is rolling hills with 0.3- to 0.6-m-tall grass growing on them.

Restored section #8

The 0.9-m-diam rocks were placed on the right side of a bend to protect the bank from erosion. On top of the rocks grows 0.15-m-high grass which extends to the 0.5-m-tall grass on the right floodplain. The water flows

deeply and calmly around the bend. Small 0.05-m rocks and sand make up the bed material. The water in the 8.2-m-wide channel touches the sand of the left bank. About 1.5 m from the water's edge, 0.3- and 0.6-m-diam rocks sit among the sparse 0.3-m-tall grass. The left floodplain is again grassy rolling hills.

Restored section #9

About 2.1 m of right bank rise above the waters edge. It is mostly covered with small 0.8-m-diam rocks and soil, but logs line the water's edge. Two large bushes grow out of the side of the right bank. The right floodplain is covered with 0.5-m-tall grass and weeds. Six large 0.6-m-diam rocks rest in the 7.6-m-wide channel. The same bed material exists in this cross section as in the previous section. There are small amounts of algae growing in the channel. Two 0.9-m-diam rocks sit on the left water's edge. Driftwood and 0.03-m-diam rock coexist on the 0.6-m-high left bank. Grass grows to a height of 0.9 m on the top of the left bank.

Restored section #10

The right bank is 0.6 m high where it meets a plateau. The 0.6-m-tall grass growing on the plateau is coupled with two large bushes. The right bank then climbs another 1.8 m. The bank is armored by large boulders and short 0.08-m-tall vegetation. Many 0.6-m-diam rocks are strewn about the 9.1-m-wide channel. No algae grows in the water. The left bank consists mostly of large 0.9-m-diam boulders. Smaller 0.15-m-diam rocks also dot the left bank. The left floodplain is rolling hills covered in 0.6-m-tall grass.

Degraded Cross-Section Descriptions

Degraded section #1

The cross section is located just downstream of a bridge and a large sandbar. The first 0.6 m of the right bank are lined with 0.1-m to 0.3-m-diam river rock. The right bank is 3 m tall and is covered with willows and 0.15-m-high grass. The channel is 15.2 m wide and is covered with 0.01-m-diam gravel. Five 0.6-m-diam boulders litter the channel, and large groups of algae make the water flow smoothly downstream. The left bank consists of 0.1-m-diam or smaller rocks. The 1.5-m-high left bank holds little vegetation and gives way to a flat floodplain. The floodplain consists of roads, houses, lawns, and 0.3-m-tall grass in small areas.

Degraded section #2

This section is approximately 4.6 m downstream and 18.3 m upstream of drop structures. The right bank rises 3.7 m from the water's edge and is covered with large angular rocks. The bank is also home to three bushes and a few clumps of 0.3-m-tall brush. The grassy floodplain slopes gently to the mountains on the right. The 0.15-m bed material in the 15.8-m-wide stream is partially covered with groups of lush, 0.15-m algae. The left bank has a three to one slope and is covered with 0.05-m grass. A few 0.6-m-diam rocks and some brush are immediately downstream of the section. The left floodplain is flat with densely grown 0.5-m-tall grass.

Degraded section #3

This section is directly upstream of an old ice house which forces the river to the left side of the channel. The right bank slopes gently, and the first 0.6 m are lined with 0.05-m-diam rocks. The remainder of the bank is covered with 0.6-m-tall grass and some small shrubs. The right floodplain extends to the mountain and nourishes grass and shrubs. The channel is 12.2 m wide and has 0.15-m bed material. The channel contains no large boulders. The left bank has a three to one slope covered with 0.3-m-diam rocks and 0.3-m-high vegetation and grass. The left floodplain is flat and grassy.

Degraded section #4

The right bank, at an eleven to one slope, slopes gently toward the mountains. The first 0.6 m of the bank are lined with 0.15-m-diam rock. From 0.6 m and extending to 0.9 m from the water's edge grows 0.08-m vegetation. The 0.6-m-tall grass and small bushes and shrubs make up the remainder of the right bank. Some 1.5-m-tall willows grow on the expansive floodplain. The channel is relatively narrow, at 8.5 m wide. The bed material consists of bare 0.15-m-diam stones which contribute to a smooth and calm flowing river. The left bank has a steep one and a half to one slope covered with 0.3- to 0.6-m-diam rocks. Small willows and 0.9-m-high vegetation dot the left bank. Chunks of concrete and pieces of rebar line the left water's edge. The left floodplain is a flat horse corral.

Degraded section #5

The 0.9-m-high right bank has a four to one slope and rises 0.15 m from the water's edge. For the first 0.9 m of the bank, 0.15-m-tall grass grows unimpeded until giving way to 0.9-m-tall bushes and shrubs. The floodplain contains 1.5-m-tall willows stretching to the mountains. Moss covers 0.15-m-diam bed material in the algae-lined 10.4-m-wide channel. The channel has a steeper slope than the preceding sections, which results in a faster,

rougher water surface. The rocky three to one sloped left bank is home to 0.08-m-diam and larger rocks. The left floodplain is again a flat horse corral.

Degraded section #6

There is a 0.15-m drop from the grassy right bank to the water's edge. Grass coupled with 0.9-m-tall willows and shrubs inhabit the right bank. The right floodplain contains 1.5-m-tall willows that extend to the mountain. The channel bed contains 0.3-m-diam and smaller rocks in the algae-laden, 14.3-m-wide stream. The rocks are mossy and slick under the rapid, ripply water. The left bank is about 0.9 m high with a three to one slope. The left bank feeds small grasses and 1.1-m tall weeds. There are 0.3-m-diam angular rocks in abundance; however, there are no shrubs. The left floodplain is flat and grassy.

Degraded section #7

There is a 0.5-m rise from the moss-covered water's edge to the grassy right overbank. The grass growing on the right overbank is 0.6 m high with relatively little shrubbery. About 1.8-m-tall willows grow about 18.3 m from the waters edge on the right floodplain. Sharp 0.3-m-diam bed material and algae are present in the channel. The slope of the channel is not as steep as the previous section, and the gradient change occurs about 9.1 m downstream of the 12.5-m-wide section. The left bank has two to one slope and is 0.6 m tall. There are three 0.3-m-diam rocks dotting the bank among 0.9-m-tall bushes. The left floodplain is a flat pasture land.

Degraded section #8

There are 0.3-m-diam rocks that are exposed in a 0.6-m drop from the top of the right bank to the water's edge. The right bank appears to be eroding, exposing the rocks. The right floodplain has densely grown bushes and willows on the top of 0.6-m drop. About 9.1 m from the water's edge, 1.5-m-high willows grow and extend to the mountains beyond. The 11.6-m-wide bed holds 0.15-m bed material. The water surface is rough from the swiftly moving water. The 0.9-m-high left bank has a four to one slope on which 0.3-m-tall grass and a couple 0.6-m-high bushes grow. The left floodplain is a flat pasture.

Degraded section #9

The cross section is located downstream of a small island. The 0.9-m-high right bank has been eroded to expose the rocks that make up the bank. The exposed rocks are held together by small clumps of grass. Some 0.6-m-tall willows grow from the top of the right bank, and the right floodplain consists

of 0.6-m-tall grass and 1.8-m-tall willows located about 6.1 m from the water's edge. The bed material in the channel is larger than in the previous sections, and there are few boulders that have a 0.6-m diameter. Algae grows abundantly in the channel that is 10.7 m wide. The steep 0.6-m rise of the left bank is covered with 0.6-m-tall grass. Brush grows thick and tall. After the steep rise, the bank flattens out for about 3 m then rises over a pile of rocks. The left floodplain is flat and grass covered.

Degraded section #10

The right bank consists of overhanging grass clumps with a 0.3-m rise to 1.15-m-tall grass. The water has eroded small fjord-looking fingers into the bank. About 1.5 m from the right water's edge, the tall willows on the floodplain thickly grow to the base of the mountain beyond. The narrow 9.1-m channel is home to algae that grow from the 0.15-m bed material. The flow in the channel splits about 2.1 m downstream of the section. The island formed by this splitting of flow is heavily eroded. The first 2.1 m of the gently sloping left bank has 0.15-m bed material that lies exposed to the sun. Grass grows beyond the rocks and extends to the 3-m-tall bushes that grow just inside of a wooden fence. The left floodplain is again flat and grass covered.

Appendix B
Microhabitat Data

B.1 Velocities - Natural Reach

Section # **N1** Approximate Discharge : 0.859 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	0.122	0.000	0.000	0.6	
2	0.152	0.335	0.213	0.2	S.P.
			0.305	0.8	
3	0.610	0.366	0.786	0.2	
			0.354	0.8	
4	1.067	0.488	0.668	0.2	
			0.335	0.8	
5	1.402	0.457	0.908	0.2	S.P.
			0.695	0.8	
6	1.981	0.366	0.860	0.2	
			0.756	0.8	
7	2.438	0.335	0.972	0.2	
			0.183	0.8	
8	2.896	0.274	0.683	0.6	
9	3.353	0.183	0.229	0.6	
10	3.962	0.183	0.668	0.6	
11	4.420	0.122	0.308	0.6	
12	5.090	0.183	0.180	0.6	S.P.
13	5.486	0.137	0.125	0.6	
14	5.944	0.107	0.143	0.6	
15	6.645	0.122	0.125	0.6	S.P.
16	7.010	0.091	0.000	0.6	
17	7.620	0.091	0.000	0.6	
18	7.925	0.091	0.119	0.6	
19	8.291	0.183	0.030	0.6	
20	9.022	0.000	0.000	0.6	

Section #	N2	Approximate Discharge :		0.644 c.m.s.	
Subsection #	**STA (from Right)**	**Depth (m)**	**Velocity (m/s)**	**At Depth (fraction)**	**Comments**
1	1.707	0.000	0.000	0.6	
2	1.981	0.061	0.003	0.6	
3	2.134	0.122	0.030	0.6	S.P.
4	2.316	0.366	0.003	0.2	S.P.
			0.000	0.8	
5	2.621	0.457	0.012	0.2	
			0.000	0.8	
6	2.972	0.457	0.030	0.2	S.P.
			0.000	0.8	
7	3.200	0.457	0.104	0.2	
			0.2[illegible]0	0.8	
8	3.505	0.366	0.564	0.2	
			0.640	0.8	
9	3.840	0.488	0.765	0.2	S.P.
			0.122	0.8	
10	4.115	0.518	0.655	0.2	
			0.046	0.8	
11	4.420	0.518	1.073	0.2	
			0.576	0.8	
12	4.770	0.579	1.021	0.2	S.P.
			0.466	0.8	
13	5.029	0.610	0.860	0.2	
			0.451	0.8	
14	5.182	0.549	0.707	0.2	
			0.046	0.8	
15	5.334	0.244	0.302	0.6	
16	5.639	0.061	0.274	0.6	
17	6.005	0.061	0.314	0.6	
18	6.279	0.274	0.338	0.6	
19	6.401	0.000	0.000	0.6	

Section # **N3** Approximate Discharge : 0.768 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	0.914	0.000	0.000	0.6	
2	1.067	0.061	0.003	0.6	
3	1.524	0.000	0.000	0.6	Rock
4	1.829	0.000	0.000	0.6	Rock
5	1.920	0.274	0.622	0.6	
6	2.027	0.229	0.896	0.6	S.P.
7	2.438	0.290	0.552	0.6	
8	2.789	0.274	0.811	0.6	S.P.
9	3.048	0.244	0.482	0.6	
10	3.353	0.259	1.146	0.6	
11	3.658	0.305	1.362	0.2	
			0.344	0.8	
12	3.871	0.305	1.490	0.2	
			0.539	0.8	
13	4.267	0.213	1.241	0.6	
14	4.572	0.274	1.036	0.6	
15	4.816	0.305	0.817	0.2	S.P.
			0.262	0.8	
16	5.182	0.274	0.408	0.6	
17	5.486	0.122	0.497	0.6	
18	5.822	0.183	0.000	0.6	S.P.
19	6.096	0.107	0.015	0.6	
20	6.431	0.000	0.000	0.6	

Section # **N4** Approximate Discharge : 0.675 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	0.914	0.000	0.000	0.6	
2	1.219	0.030	0.000	0.6	
3	1.524	0.030	0.000	0.6	
4	1.829	0.030	0.000	0.6	
5	2.134	0.000	0.000	0.6	
6	2.499	0.122	0.165	0.6	S.P.
7	2.743	0.091	0.530	0.6	
8	3.048	0.152	0.515	0.6	
9	3.353	0.061	0.610	0.6	
10	3.658	0.168	0.823	0.6	
11	3.962	0.213	0.287	0.6	
12	4.267	0.213	0.552	0.6	
13	4.511	0.290	0.634	0.6	S.P.
14	4.877	0.366	1.082	0.2	
			0.360	0.8	
15	5.182	0.305	0.701	0.2	
			0.347	0.8	
16	5.471	0.274	0.332	0.6	S.P.
17	5.852	0.305	1.686	0.2	
			1.125	0.8	
18	6.126	0.274	0.604	0.6	
19	6.553	0.213	0.543	0.6	
20	7.010	0.183	0.582	0.6	
21	7.315	0.183	0.442	0.6	S.P.
22	7.833	0.000	0.000	0.6	

Section #	N5	Approximate Discharge :		0.816 c.m.s.	
Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	5.334	0.000	0.000	0.6	
2	5.852	0.091	0.421	0.6	S.P.
3	6.248	0.152	0.235	0.6	
4	6.858	0.152	0.213	0.6	Behind rock
5	7.193	0.091	0.256	0.6	S.P.
6	7.620	0.122	1.149	0.6	
7	7.925	0.152	1.024	0.6	
8	8.230	0.152	0.902	0.6	
9	8.534	0.213	0.975	0.6	
10	8.992	0.183	0.494	0.6	
11	9.296	0.244	0.704	0.6	
12	9.601	0.198	0.411	0.6	
13	9.936	0.183	0.457	0.6	S.P.
14	10.211	0.259	0.698	0.6	
15	10.516	0.274	0.792	0.6	
16	10.820	0.381	0.823	0.2	S.P.
			0.442	0.8	
17	11.125	0.518	0.808	0.2	
			0.613	0.8	
18	11.430	0.427	0.823	0.2	
			0.415	0.8	
19	11.704	0.396	0.204	0.2	S.P.
			0.040	0.8	
20	12.040	0.305	0.140	0.2	
			0.152	0.8	
21	12.344	0.183	0.049	0.6	
22	12.649	0.000	0.000	0.6	

Section # N6 Approximate Discharge : 0.772 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	2.804	0.000	0.000	0.6	
2	3.200	0.152	-0.116	0.6	
3	3.658	0.229	-0.067	0.6	
4	4.145	0.335	0.091	0.2	
			-0.055	0.8	
5	4.602	0.427	0.372	0.2	S.P.
			-0.052	0.8	
6	5.060	0.457	0.482	0.2	
			-0.027	0.8	
7	5.578	0.427	0.558	0.2	
			0.119	0.8	
8	6.005	0.442	0.683	0.2	
			0.134	0.8	
9	6.370	0.396	0.649	0.2	S.P.
			0.314	0.8	
10	6.919	0.549	0.707	0.2	
			0.229	0.8	
11	7.315	0.579	0.908	0.2	
			0.290	0.8	
12	7.650	0.610	0.710	0.2	S.P.
			0.162	0.8	
13	8.138	0.549	0.500	0.2	
			0.070	0.8	
14	8.534	0.564	0.308	0.2	
			-0.018	0.8	
15	8.900	0.518	0.192	0.2	S.P.
			-0.070	0.8	
16	9.327	0.594	0.168	0.2	
			-0.052	0.8	
17	9.647	0.640	0.101	0.2	
			-0.055	0.8	
18	10.058	0.518	0.037	0.2	
			-0.024	0.8	
19	10.516	0.503	0.006	0.2	
			-0.067	0.8	
20	11.125	0.381	-0.027	0.2	
			-0.024	0.8	
21	11.887	0.000	0.000	0.6	

Section # N7 Approximate Discharge : 0.927 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	2.347	0.000	0.000	0.6	
2	3.810	0.000	0.000	0.6	
3	3.962	0.091	0.000	0.6	
4	4.572	0.152	0.226	0.6	
5	5.182	0.198	0.259	0.6	
6	5.791	0.122	0.457	0.6	
7	5.974	0.152	0.399	0.6	S.P.
8	6.706	0.152	0.418	0.6	
9	7.330	0.229	0.180	0.6	S.P.
10	7.894	0.091	0.183	0.6	
11	8.656	0.152	0.866	0.6	S.P.
12	9.388	0.152	0.725	0.6	
13	9.815	0.213	0.369	0.6	
14	10.455	0.152	0.485	0.6	S.P.
15	11.156	0.244	0.802	0.18	
16	11.796	0.244	0.942	0.6	S.P.
17	12.680	0.244	0.302	0.6	
18	13.716	0.122	0.600	0.6	S.P.
19	14.630	0.091	0.387	0.6	
20	15.819	0.122	0.034	0.6	
21	16.124	0.000	0.000	0.6	

Section # **N8** Approximate Discharge : 0.773 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	1.067	0.000	0.000	0.6	
2	1.524	0.061	0.000	0.6	
3	1.829	0.091	0.186	0.6	
4	2.134	0.091	0.067	0.6	
5	2.438	0.152	0.402	0.6	S.P.
6	2.896	0.152	0.573	0.6	
7	3.200	0.213	0.335	0.6	Behind rock
8	3.505	0.244	0.588	0.6	
9	3.810	0.274	0.686	0.6	
10	4.115	0.274	0.158	0.6	
11	4.420	0.274	0.561	0.6	
12	4.724	0.290	1.052	0.6	S.P.
13	4.877	0.274	1.183	0.6	
14	5.182	0.244	0.942	0.6	
15	5.578	0.244	1.000	0.6	S.P.
16	5.791	0.305	1.295	0.2	
			0.137	0.8	
17	6.096	0.274	1.033	0.6	
18	6.401	0.244	0.671	0.6	
19	6.706	0.213	0.283	0.6	
20	7.010	0.183	0.399	0.6	S.P.
21	7.468	0.000	0.000	0.6	

Section # **N9** Approximate Discharge : 0.723 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	1.372	0.000	0.000	0.6	
2	1.829	0.549	0.927	0.2	S.P.
			0.320	0.8	
3	2.438	0.457	0.396	0.2	
			0.122	0.8	
4	2.957	0.290	0.247	0.6	S.P.
5	3.505	0.244	0.122	0.6	
6	4.115	0.122	0.695	0.6	
7	4.572	0.122	0.335	0.6	S.P.
8	5.182	0.091	0.802	0.6	
9	5.486	0.152	0.869	0.6	
10	5.791	0.122	0.177	0.6	Behind rock
11	6.096	0.244	0.927	0.6	
12	6.401	0.244	0.933	0.6	
13	6.706	0.244	0.085	0.6	Behind rock
14	7.010	0.213	0.588	0.6	
15	7.315	0.213	0.384	0.6	
16	7.620	0.183	0.555	0.6	
17	7.925	0.183	0.753	0.6	S.P.
18	8.077	0.213	0.472	0.6	
19	8.382	0.122	0.302	0.6	
20	8.687	0.091	0.329	0.6	
21	8.992	0.000	0.000	0.6	

Section # **N10** Approximate Discharge : 0.898 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	3.353	0.000	0.000	0.6	
2	3.810	0.061	0.238	0.6	
3	4.267	0.244	0.250	0.6	
4	4.877	0.122	0.323	0.6	
5	5.425	0.183	0.488	0.6	S.P.
6	5.639	0.274	0.628	0.6	
7	6.096	0.183	0.692	0.6	In trees
8	6.401	0.274	0.564	0.6	In trees
9	6.858	0.290	0.735	0.6	S.P.
10	7.468	0.274	0.332	0.6	
11	7.925	0.335	0.802	0.2	S.P.
			0.162	0.8	
12	8.382	0.274	0.805	0.6	
13	8.839	0.213	0.573	0.6	
14	9.296	0.183	0.442	0.6	
15	9.754	0.183	0.515	0.6	
16	10.211	0.244	0.387	0.6	S.P.
17	10.668	0.244	0.460	0.6	
18	11.125	0.183	0.162	0.6	
19	11.582	0.183	0.213	0.6	
20	12.040	0.152	0.143	0.6	
21	12.497	0.091	0.384	0.6	S.P.
22	12.954	0.152	0.250	0.6	
23	13.411	0.061	0.000	0.6	
24	13.868	0.000	0.000	0.6	

B.2 Velocities - Restored Reach

Section # **R1** Approximate Discharge : 1.045 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	1.798	0.000	0.000	0.6	
2	2.408	0.000	0.000	0.6	Large rock
3	2.438	0.290	0.320	0.6	
4	2.743	0.351	0.954	0.2	
			-0.070	0.8	Behind rock
5	3.078	0.366	0.582	0.2	
			0.421	0.8	
6	3.353	0.366	0.692	0.2	
			0.308	0.8	
7	3.597	0.335	0.677	0.2	S.P.
			0.933	0.8	
8	3.962	0.366	1.033	0.2	
			0.271	0.8	
9	4.298	0.518	0.789	0.2	
			0.479	0.8	
10	4.572	0.488	1.183	0.2	S.P.
			0.293	0.8	
11	4.877	0.396	0.927	0.2	
			0.299	0.8	
12	5.182	0.335	1.192	0.2	
			0.460	0.8	
13	5.563	0.229	0.896	0.6	S.P.
14	5.791	0.244	0.969	0.6	
15	6.187	0.244	0.805	0.6	
16	6.401	0.290	0.317	0.6	
17	6.736	0.274	0.661	0.6	
18	7.071	0.290	0.067	0.6	
19	7.315	0.122	0.402	0.6	S.P.
20	7.620	0.198	0.363	0.6	
21	7.925	0.152	0.180	0.6	
22	8.443	0.000	0.000	0.6	

Section # **R2** Approximate Discharge : 0.816 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	2.743	0.000	0.000	0.6	
2	3.200	0.091	-0.043	0.6	
3	3.658	0.244	0.012	0.6	
4	4.176	0.366	0.125	0.2	
			0.085	0.8	
5	4.542	0.381	0.338	0.2	S.P.
			0.168	0.8	
6	5.029	0.381	0.372	0.2	
			0.125	0.8	
7	5.486	0.366	0.482	0.2	
			0.274	0.8	
8	5.852	0.335	0.494	0.2	
			0.274	0.8	
9	6.279	0.274	0.500	0.6	S.P.
10	6.706	0.396	0.524	0.2	
			0.067	0.8	
11	7.193	0.305	0.509	0.2	
			0.366	0.8	
12	7.620	0.366	0.454	0.2	
			-0.037	0.8	Behind rock
13	8.382	0.427	0.564	0.2	S.P.
			0.216	0.8	
14	8.870	0.274	0.351	0.6	
15	9.357	0.366	0.341	0.2	S.P.
			0.140	0.8	
16	9.936	0.396	0.387	0.2	
			0.149	0.8	
17	10.394	0.381	0.427	0.2	
			0.165	0.8	
18	10.866	0.366	0.332	0.2	S.P.
			0.189	0.8	
19	11.582	0.457	0.107	0.2	S.P.
			0.012	0.8	
20	12.192	0.305	0.015	0.2	
			0.009	0.8	
21	12.893	0.000	0.000	0.6	

Section # **R3** Approximate Discharge : 1.010 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	2.042	0.000	0.000	0.6	
2	2.408	0.122	0.021	0.6	Moss
3	2.743	0.122	0.082	0.6	
4	3.048	0.165	0.287	0.6	
5	3.597	0.183	0.728	0.6	S.P.
6	3.962	0.305	1.061	0.2	
			0.040	0.8	
7	4.298	0.183	0.939	0.6	
8	4.755	0.274	0.634	0.6	
9	5.121	0.152	1.082	0.6	S.P.
10	5.364	0.274	0.896	0.6	
11	5.761	0.351	1.356	0.2	S.P.
			0.671	0.8	
12	6.157	0.366	1.103	0.2	
			0.506	0.8	
13	6.645	0.274	0.878	0.6	
14	7.102	0.290	0.308	0.6	
15	7.559	0.198	0.850	0.6	S.P.
16	7.986	0.213	0.430	0.6	In trees
17	8.534	0.244	0.204	0.6	In trees
18	8.900	0.183	0.171	0.6	S.P.
19	9.296	0.000	0.000	0.6	

Section # **R4** Approximate Discharge : 1.069 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	3.505	0.000	0.000	0.6	
2	4.115	0.152	0.445	0.6	
3	4.572	0.152	0.341	0.6	S.P.
4	5.182	0.213	0.469	0.6	
5	5.944	0.274	0.457	0.6	
6	6.553	0.274	0.960	0.6	
7	6.828	0.335	1.472	0.2	S.P.
			0.335	0.8	
8	7.315	0.366	1.335	0.2	
			0.369	0.8	
9	7.772	0.305	1.378	0.2	
			0.585	0.8	
10	8.169	0.274	0.158	0.6	S.P.
11	8.992	0.244	0.957	0.6	
12	9.449	0.274	0.832	0.6	
13	9.906	0.244	0.472	0.6	
14	10.363	0.183	0.021	0.6	
15	10.820	0.122	0.390	0.6	
16	11.278	0.030	0.000	0.6	
17	11.735	0.000	0.000	0.6	
18	12.192	0.061	0.000	0.6	
19	12.649	0.061	0.000	0.6	
20	13.106	0.091	0.000	0.6	
21	13.564	0.046	0.000	0.6	
22	13.716	0.000	0.000	0.6	

Section # **R5** Approximate Discharge : 0.942 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	4.267	0.000	0.000	0.6	
2	4.724	0.046	0.000	0.6	Moss
3	5.182	0.152	0.101	0.6	Moss
4	5.639	0.213	0.174	0.6	
5	6.066	0.229	0.171	0.6	S.P.
6	6.553	0.107	0.424	0.6	
7	7.010	0.076	0.555	0.6	
8	7.620	0.152	0.732	0.6	
9	8.077	0.762	0.738	0.2	S.P.
			0.091	0.8	
10	8.534	0.152	0.847	0.6	
11	8.992	0.213	0.613	0.6	
12	9.449	0.259	0.533	0.6	
13	9.906	0.396	0.579	0.2	
			0.073	0.8	
14	10.363	0.274	0.539	0.6	
15	10.820	0.274	0.357	0.6	S.P.
16	11.278	0.274	0.384	0.6	
17	11.887	0.335	0.424	0.2	Moss
			0.006	0.8	Moss
18	12.344	0.290	0.314	0.6	Moss
19	12.802	0.274	0.418	0.6	
20	13.259	0.290	0.372	0.6	S.P.
21	13.716	0.183	0.034	0.6	
22	14.173	0.000	0.000	0.6	

Section # R6 Approximate Discharge : 0.928 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	3.048	0.000	0.000	0.6	
2	3.505	0.030	0.000	0.6	
3	3.962	0.091	0.101	0.6	S.P.
4	4.420	0.122	0.238	0.6	
5	4.877	0.091	0.351	0.6	
6	5.334	0.122	0.034	0.6	Behind rock
7	5.791	0.091	0.000	0.6	Behind rock
8	6.248	0.183	0.558	0.6	
9	6.706	0.198	0.591	0.6	
10	7.010	0.183	0.244	0.6	S.P.
11	7.529	0.168	0.116	0.6	S.P.
12	8.230	0.274	0.262	0.6	
13	8.687	0.290	0.579	0.6	
14	9.144	0.274	0.518	0.6	
15	9.601	0.335	0.515	0.2	
			0.067	0.8	Moss
16	10.058	0.396	0.671	0.2	
			0.287	0.8	
17	10.668	0.457	0.549	0.2	
			0.396	0.8	
18	11.278	0.427	0.594	0.2	
			0.024	0.8	Moss
19	11.887	0.457	0.869	0.2	
			0.137	0.8	Moss
20	12.649	0.411	0.518	0.2	
			0.387	0.8	
21	12.954	0.000	0.000	0.6	

Section # **R7** Approximate Discharge : 1.001 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	3.505	0.000	0.000	0.6	
2	3.810	0.122	0.030	0.6	
3	4.115	0.122	0.101	0.6	
4	4.420	0.061	0.165	0.6	
5	4.724	0.137	0.265	0.6	
6	4.968	0.183	0.354	0.6	S.P.
7	5.486	0.152	0.427	0.6	
8	5.791	0.213	0.396	0.6	
9	6.096	0.168	0.518	0.6	
10	6.401	0.244	0.518	0.6	
11	6.706	0.229	0.768	0.6	
12	6.919	0.244	0.811	0.6	S.P.
13	7.315	0.305	0.850	0.2	
			0.183	0.8	Behind rock
14	7.772	0.366	0.930	0.2	
			0.549	0.8	
15	8.230	0.427	1.082	0.2	
			0.064	0.8	
16	8.534	0.335	1.021	0.2	
			0.564	0.8	
17	8.839	0.335	1.003	0.2	S.P.
			0.671	0.8	
18	9.449	0.427	0.942	0.2	
			0.366	0.8	
19	9.906	0.366	0.607	0.2	
			0.000	0.8	Behind rock
20	10.363	0.244	0.335	0.6	
21	10.729	0.213	0.119	0.6	S.P. & Moss
22	10.820	0.000	0.000	0.6	

Section # **R8** Approximate Discharge : 0.979 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	7.315	0.000	0.000	0.6	
2	7.468	0.183	0.000	0.6	S.P.
3	7.925	0.396	0.247	0.2	
			0.000	0.8	
4	8.382	0.457	0.351	0.2	
			0.030	0.8	
5	8.839	0.488	0.442	0.2	
			0.183	0.8	
6	9.296	0.610	0.594	0.2	
			0.259	0.8	
7	9.936	0.884	0.646	0.2	
			0.244	0.8	
8	10.363	0.975	0.579	0.2	
			0.204	0.8	
9	10.820	1.097	0.457	0.2	
			0.146	0.8	
10	11.217	1.128	0.402	0.2	S.P.
			0.091	0.8	
11	11.582	1.036	0.250	0.2	
			0.101	0.8	
12	12.040	0.914	0.034	0.2	
			0.018	0.8	
13	12.497	0.853	0.000	0.2	
			0.000	0.8	
14	12.954	0.671	0.000	0.2	
			0.000	0.8	
15	13.411	0.549	0.000	0.2	
			0.000	0.8	
16	13.868	0.427	0.000	0.2	
			0.000	0.8	
17	14.326	0.244	0.000	0.6	
18	14.783	0.183	0.000	0.6	S.P.
19	15.240	0.152	0.000	0.6	
20	15.697	0.122	0.000	0.6	
21	16.154	0.000	0.000	0.6	

Section # **R9** Approximate Discharge : 0.999 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	4.877	0.000	0.000	0.6	
2	5.334	0.152	0.168	0.6	
3	5.639	0.244	0.728	0.6	
4	5.944	0.274	0.482	0.6	
5	6.157	0.274	0.311	0.6	S.P.
6	6.492	0.122	0.570	0.6	
7	6.858	0.000	0.000	0.6	Rock
8	7.468	0.335	0.655	0.2	
			0.320	0.8	
9	7.772	0.274	1.210	0.6	S.P.
10	8.077	0.274	1.076	0.6	
11	8.382	0.274	1.234	0.6	
12	8.839	0.274	1.082	0.6	
13	9.144	0.305	0.512	0.2	
			0.000	0.8	Behind rock
14	9.601	0.290	0.320	0.6	
15	9.906	0.335	0.628	0.2	S.P.
			0.716	0.8	
16	10.363	0.290	0.631	0.6	
17	10.820	0.259	0.341	0.6	
18	11.125	0.213	0.000	0.6	Behind rock
19	11.582	0.122	0.963	0.6	
20	11.826	0.213	0.735	0.6	S.P.
21	12.192	0.122	0.390	0.6	
22	12.497	0.000	0.000	0.6	

Section # **R10** Approximate Discharge : 1.002 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	5.486	0.000	0.000	0.6	
2	5.944	0.152	0.393	0.6	
3	6.157	0.183	0.829	0.6	S.P.
4	6.858	0.213	0.640	0.6	
5	7.315	0.244	0.701	0.6	
6	7.620	0.274	0.945	0.6	S.P.
7	8.230	0.259	0.485	0.6	
8	8.687	0.213	0.000	0.6	Behind rock
9	9.144	0.183	1.122	0.6	
10	9.601	0.183	0.634	0.6	
11	10.058	0.335	0.253	0.2	
			0.122	0.8	
12	10.516	0.274	0.863	0.6	S.P.
13	11.125	0.168	0.219	0.6	
14	11.582	0.137	0.823	0.6	
15	12.040	0.152	0.335	0.6	
16	12.497	0.198	0.512	0.6	
17	12.802	0.091	0.719	0.6	
18	13.259	0.107	0.792	0.6	
19	13.868	0.290	0.168	0.6	
20	14.326	0.290	0.402	0.6	
21	14.630	0.000	0.000	0.6	

B.3 Velocities - Degraded Reach

Section # **D1** Approximate Discharge : 0.804 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	0.396	0.000	0.000	0.6	
2	0.610	0.091	0.000	0.6	
3	0.945	0.274	0.466	0.6	S.P.
4	1.524	0.305	0.082	0.6	Moss
5	2.134	0.213	0.082	0.6	Moss
6	2.743	0.213	0.573	0.6	
7	3.353	0.183	0.018	0.6	Moss
8	3.962	0.152	0.030	0.6	Behind Rock
9	5.486	0.198	0.000	0.6	Moss
10	6.096	0.274	0.094	0.6	
11	6.767	0.366	0.165	0.2	S.P.
			0.143	0.8	
12	7.315	0.411	0.351	0.2	
			0.396	0.8	
13	7.407	0.000	0.000	0.6	
14	8.321	0.000	0.000	0.6	Rock
15	8.534	0.335	0.125	0.2	Rock
			0.219	0.8	
16	9.144	0.198	0.030	0.6	
17	9.693	0.152	0.238	0.6	S.P. & Moss
18	10.363	0.244	0.616	0.6	
19	10.973	0.259	0.561	0.6	
20	11.582	0.244	0.646	0.6	
21	12.192	0.229	0.549	0.6	S.P.
22	12.954	0.213	0.311	0.6	
23	13.716	0.244	0.466	0.6	
24	14.478	0.168	0.162	0.6	
25	15.331	0.000	0.000	0.6	

Section # **D2** **Approximate Discharge :** **1.035 c.m.s**

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	1.402	0.000	0.000	0.6	
2	1.951	0.183	0.003	0.6	Behind rock
3	2.408	0.229	0.107	0.6	S.P.
4	3.170	0.274	0.003	0.6	Moss
5	3.962	0.381	0.320	0.2	
			0.012	0.8	
6	4.450	0.305	0.000	0.6	S.P. & Moss
7	4.633	0.335	0.018	0.2	Moss
			0.000	0.8	
8	5.974	0.152	0.000	0.6	Moss
9	6.401	0.168	0.314	0.6	
10	6.858	0.198	0.290	0.6	S.P.
11	7.163	0.213	0.268	0.6	
12	7.925	0.229	0.265	0.6	
13	8.687	0.305	0.408	0.2	
			0.244	0.8	
14	9.723	0.396	0.628	0.2	S.P.
			0.497	0.8	
15	10.668	0.381	0.728	0.2	
			0.012	0.8	Moss
16	11.430	0.335	0.607	0.2	
			0.268	0.8	
17	12.497	0.244	0.771	0.6	
18	13.259	0.152	0.710	0.6	
19	14.021	0.107	0.439	0.6	
20	14.630	0.000	0.000	0.6	
21	15.545	0.061	0.472	0.6	
22	16.154	0.000	0.000	0.6	
23	16.703	0.091	0.274	0.6	S.P.
24	17.282	0.000	0.000	0.6	

Section #	D3	Approximate Discharge :		1.011 c.m.s.	
Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	1.829	0.000	0.000	0.6	
2	2.438	0.061	0.232	0.6	
3	3.322	0.152	0.460	0.6	S.P.
4	3.658	0.137	0.427	0.6	
5	4.267	0.183	0.524	0.6	
6	4.877	0.183	0.552	0.6	
7	5.517	0.305	0.683	0.2	S.P.
			0.332	0.8	
8	6.096	0.305	0.783	0.2	
			0.457	0.8	
9	6.706	0.244	0.613	0.6	
10	7.315	0.274	0.637	0.6	
11	8.138	0.229	0.387	0.6	S.P.
12	8.534	0.244	0.418	0.6	
13	9.144	0.274	0.357	0.6	
14	9.754	0.259	0.021	0.6	Moss
15	10.394	0.305	0.482	0.2	S.P.
			0.305	0.8	
16	10.973	0.305	0.335	0.2	
			0.213	0.8	Moss
17	11.582	0.305	0.466	0.2	
			0.091	0.8	Moss
18	12.314	0.366	0.213	0.2	S.P. Moss
			0.091	0.8	Moss
19	12.802	0.274	0.009	0.6	
20	13.411	0.122	0.213	0.6	
21	13.746	0.000	0.000	0.6	

Section # **D4** Approximate Discharge : 0.948 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	6.858	0.000	0.000	0.6	
2	7.315	0.122	0.098	0.6	
3	7.772	0.152	0.213	0.6	
4	8.230	0.183	0.305	0.6	S.P.
5	8.687	0.198	0.335	0.6	
6	9.144	0.274	0.351	0.6	
7	9.601	0.290	0.299	0.6	
8	9.906	0.274	0.430	0.6	
9	10.363	0.305	0.591	0.2	
			0.229	0.8	
10	10.820	0.335	0.600	0.2	
			0.351	0.8	
11	11.278	0.335	0.655	0.2	
			0.427	0.8	
12	11.674	0.366	0.625	0.2	S.P.
			0.244	0.8	
13	12.192	0.381	0.741	0.2	
			0.533	0.8	
14	12.649	0.457	0.838	0.2	
			0.402	0.8	
15	13.106	0.488	0.744	0.2	
			0.482	0.8	
16	13.564	0.518	0.536	0.2	S.P.
			0.012	0.8	
17	14.021	0.411	0.107	0.2	
			0.165	0.8	
18	14.478	0.244	0.000	0.6	Behind rock
19	14.630	0.152	0.000	0.6	S.P.
20	15.088	0.091	0.000	0.6	Behind rock
21	15.545	0.000	0.000	0.6	

Section # **D5** Approximate Discharge : 0.809 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	1.829	0.000	0.000	0.6	
2	2.286	0.122	0.610	0.6	
3	2.896	0.122	0.357	0.6	
4	3.200	0.152	0.171	0.6	
5	3.658	0.152	0.311	0.6	
6	4.267	0.152	0.259	0.6	
7	4.572	0.183	0.046	0.6	S.P. & Moss
8	5.029	0.244	0.680	0.6	
9	5.486	0.213	0.914	0.6	
10	6.096	0.274	0.768	0.6	
11	6.553	0.183	0.640	0.6	S.P.
12	7.010	0.244	0.131	0.6	Moss
13	7.468	0.244	0.411	0.6	
14	7.925	0.274	0.201	0.6	Moss
15	8.230	0.335	0.960	0.2	S.P.
			0.500	0.8	Moss
16	8.839	0.244	0.789	0.6	
17	9.296	0.274	0.329	0.6	S.P.
18	9.906	0.122	0.122	0.6	
19	10.363	0.091	0.152	0.6	S.P.
20	10.973	0.061	0.003	0.6	
21	11.582	0.061	0.000	0.6	
22	12.040	0.000	0.000	0.6	

Section # **D6** Approximate Discharge : 0.889 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	0.701	0.000	0.000	0.6	
2	1.219	0.183	0.009	0.6	Moss
3	1.829	0.168	0.561	0.6	
4	2.469	0.076	0.061	0.6	S.P. & Moss
5	3.200	0.213	0.259	0.6	
6	3.962	0.213	0.725	0.6	
7	4.572	0.305	0.762	0.2	
			0.378	0.8	
8	5.334	0.274	0.152	0.6	Behind rock
9	5.700	0.259	0.466	0.6	S.P. & Moss
10	6.401	0.259	0.457	0.6	
11	7.010	0.183	0.640	0.6	
12	7.650	0.213	0.366	0.6	S.P.
13	8.230	0.137	0.860	0.6	
14	8.839	0.183	0.521	0.6	
15	9.510	0.137	0.293	0.6	S.P. & Moss
16	10.211	0.122	0.457	0.6	
17	10.973	0.091	0.305	0.6	
18	11.735	0.091	0.119	0.6	
19	12.253	0.076	0.268	0.6	S.P.
20	13.106	0.122	0.360	0.6	
21	13.594	0.152	0.024	0.6	S.P. & Moss
22	14.326	0.061	0.037	0.6	
23	14.630	0.000	0.000	0.6	

Section # **D7** Approximate Discharge : 0.928 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	2.042	0.000	0.000	0.6	
2	2.286	0.274	0.009	0.6	S.P. & Moss
3	2.896	0.152	0.201	0.6	
4	3.505	0.152	0.168	0.6	
5	4.115	0.168	0.268	0.6	
6	4.877	0.122	0.427	0.6	
7	5.334	0.152	0.268	0.6	
8	5.944	0.152	0.411	0.6	
9	6.767	0.168	0.469	0.6	S.P.
10	7.315	0.213	0.366	0.6	
11	7.925	0.229	0.338	0.6	
12	8.534	0.183	0.512	0.6	
13	9.144	0.244	0.457	0.6	Moss
14	9.936	0.320	0.655	0.2	S.P.
			0.296	0.8	
15	10.363	0.244	0.418	0.6	
16	10.973	0.259	0.488	0.6	
17	11.582	0.213	0.561	0.6	
18	12.192	0.213	0.607	0.6	
19	12.802	0.305	0.411	0.2	
			0.232	0.8	
20	13.411	0.244	0.250	0.6	S.P.
21	14.021	0.152	0.040	0.6	Moss
22	14.630	0.000	0.000	0.6	

Section #	D8	Approximate Discharge :	0.804 c.m.s.		
Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	1.067	0.000	0.000	0.6	
2	1.524	0.213	0.049	0.6	
3	2.134	0.244	0.399	0.6	
4	2.469	0.274	0.171	0.6	S.P.
5	3.048	0.259	0.442	0.6	
6	3.658	0.274	0.268	0.6	
7	4.267	0.183	0.299	0.6	
8	4.877	0.183	0.070	0.6	
9	5.395	0.183	0.360	0.6	S.P.
10	6.096	0.152	0.299	0.6	
11	6.706	0.244	0.351	0.6	
12	7.315	0.274	0.497	0.6	
13	7.925	0.305	0.558	0.2	
			0.076	0.8	
14	8.534	0.366	0.543	0.2	
			0.000	0.8	Behind rock
15	9.144	0.427	0.588	0.2	S.P.
			0.308	0.8	
16	9.754	0.274	0.439	0.6	
17	10.363	0.274	0.381	0.6	
18	10.973	0.183	0.012	0.6	Moss
19	11.460	0.091	0.006	0.6	S.P. & Moss
20	11.887	0.076	0.229	0.6	
21	12.497	0.000	0.000	0.6	

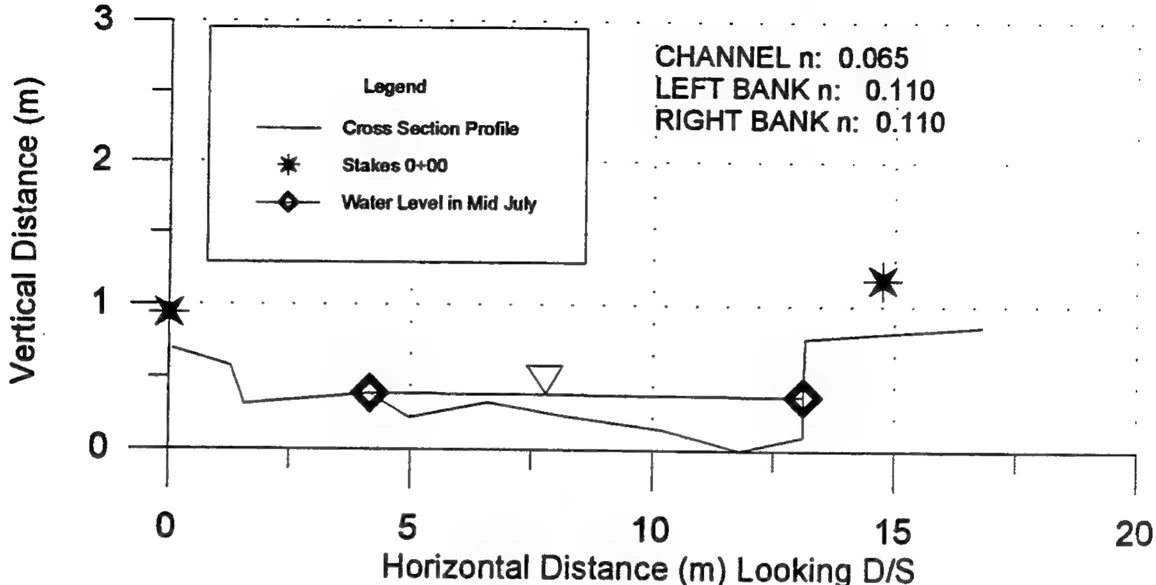
Section # **D9** Approximate Discharge : 0.846 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	1.676	0.000	0.000	0.6	
2	2.134	0.152	0.000	0.6	
3	2.621	0.213	0.055	0.6	S.P.
4	3.048	0.335	0.482	0.2	
			0.098	0.8	
5	3.505	0.335	0.823	0.2	
			0.329	0.8	
6	4.023	0.366	1.052	0.2	S.P.
			0.335	0.8	
7	4.420	0.366	0.991	0.2	
			0.299	0.8	
8	4.877	0.457	1.082	0.2	
			0.183	0.8	
9	5.334	0.488	0.887	0.2	
			0.344	0.8	
10	5.944	0.457	0.664	0.2	
			0.061	0.8	
11	6.309	0.396	0.604	0.2	S.P.
			0.201	0.8	
12	7.010	0.244	0.021	0.6	Behind rock
13	7.742	0.183	0.073	0.6	S.P.
14	8.230	0.183	0.043	0.6	
15	8.687	0.152	0.034	0.6	
16	9.144	0.213	0.040	0.6	
17	9.906	0.213	0.000	0.6	S.P.
18	10.363	0.335	0.000	0.2	Behind rock
			0.000	0.8	Behind rock
19	10.820	0.244	0.116	0.6	S.P.
20	11.582	0.183	0.021	0.6	Behind rock
21	12.344	0.000	0.000	0.6	

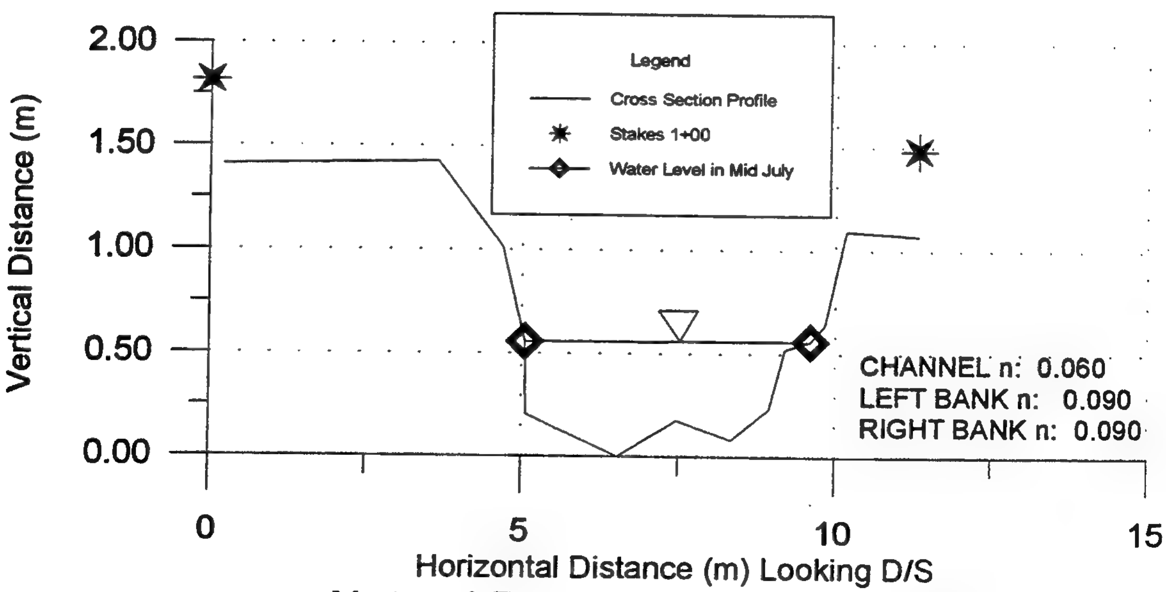
Section #	D10	Approximate Discharge :	0.861 c.m.s.

Subsection #	STA (from Right)	Depth (m)	Velocity (m/s)	At Depth (fraction)	Comments
1	3.505	0.000	0.000	0.6	
2	3.749	0.061	0.198	0.6	S.P.
3	4.267	0.183	0.000	0.6	Behind rock
4	4.724	0.213	0.482	0.6	
5	5.273	0.274	0.098	0.6	S.P. & Moss
6	5.791	0.274	0.808	0.6	
7	6.248	0.244	0.610	0.6	
8	6.706	0.244	0.235	0.6	
9	7.163	0.274	0.853	0.6	
10	7.620	0.274	0.853	0.6	
11	8.077	0.335	0.866	0.2	
			0.320	0.8	
12	8.534	0.274	0.518	0.6	
13	8.839	0.335	0.832	0.2	
			0.549	0.8	
14	9.235	0.274	0.564	0.6	S.P.
15	9.449	0.274	0.655	0.6	
16	9.906	0.213	0.378	0.6	
17	10.455	0.091	0.000	0.6	S.P.
18	11.125	0.091	0.094	0.6	
19	11.582	0.091	0.067	0.6	
20	12.040	0.091	0.000	0.6	
21	12.649	0.000	0.000	0.6	

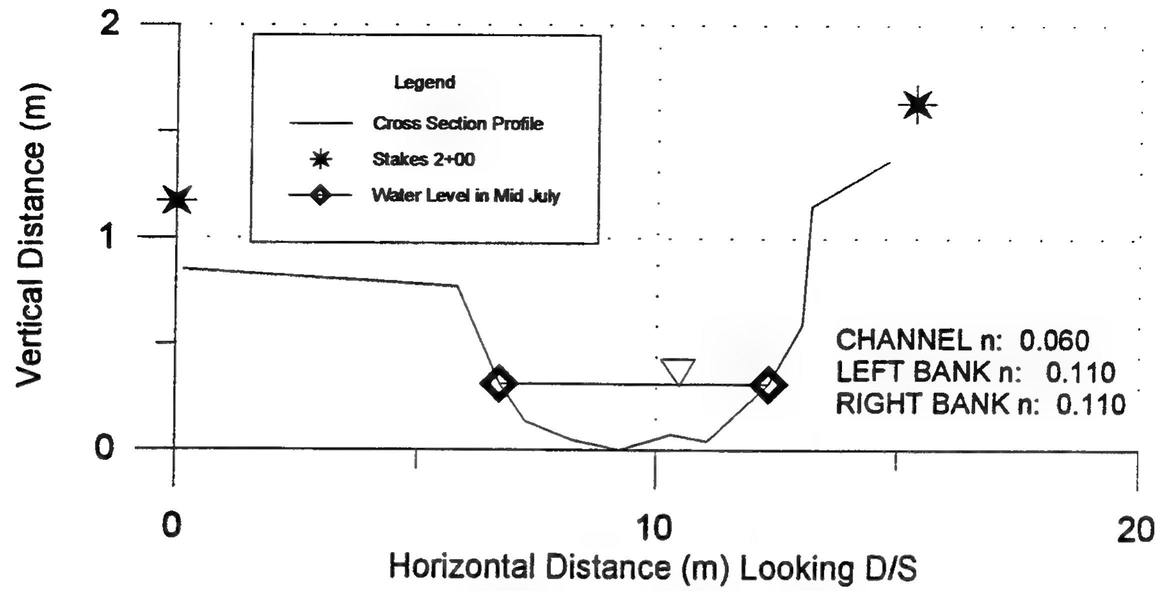
B.4 Cross Sections - Natural Reach



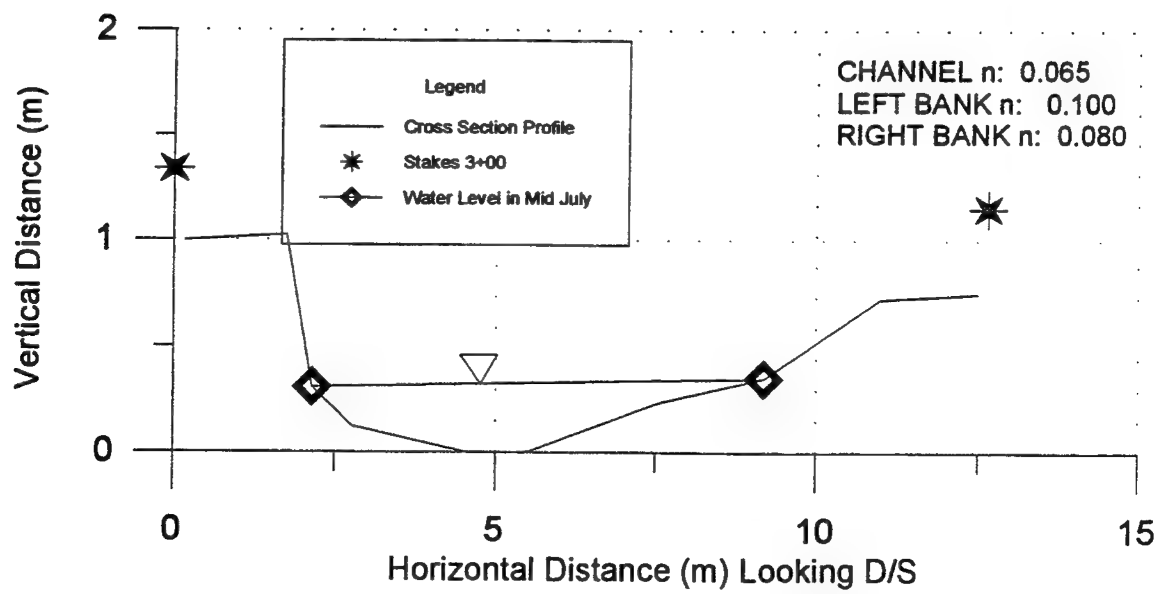
Natural Reach Cross Section N1



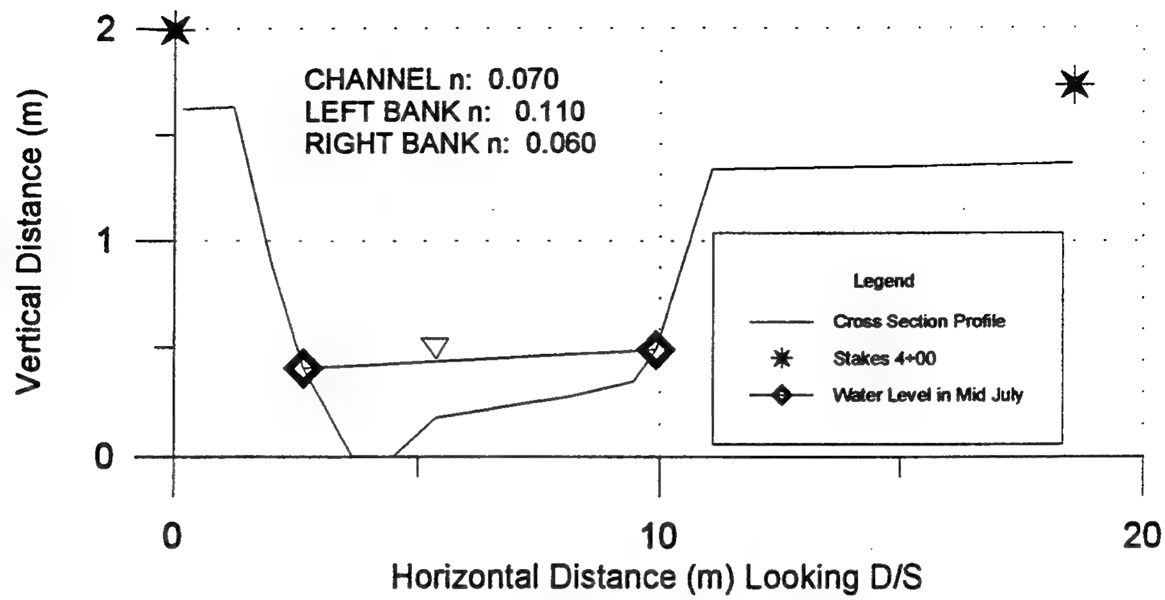
Natural Reach Cross Section N2



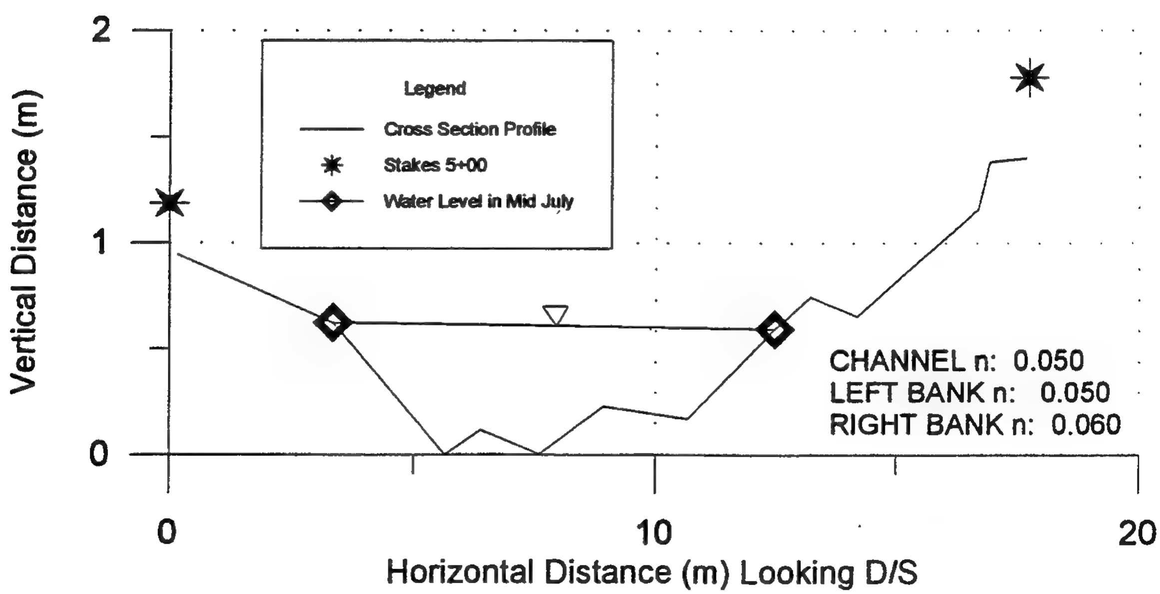
Natural Reach Cross Section N3



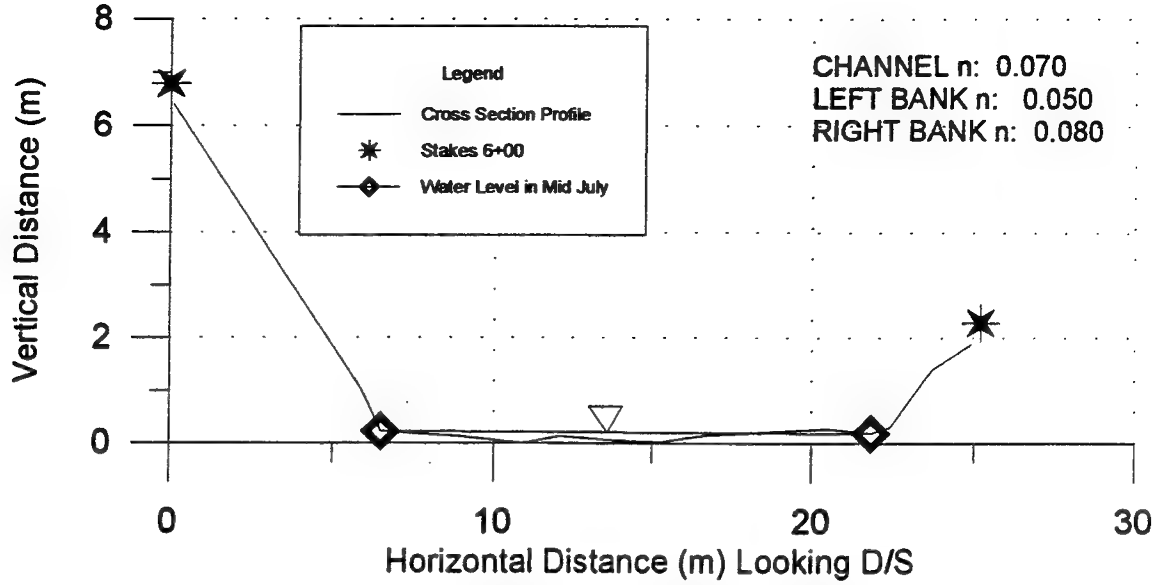
Natural Reach Cross Section N4



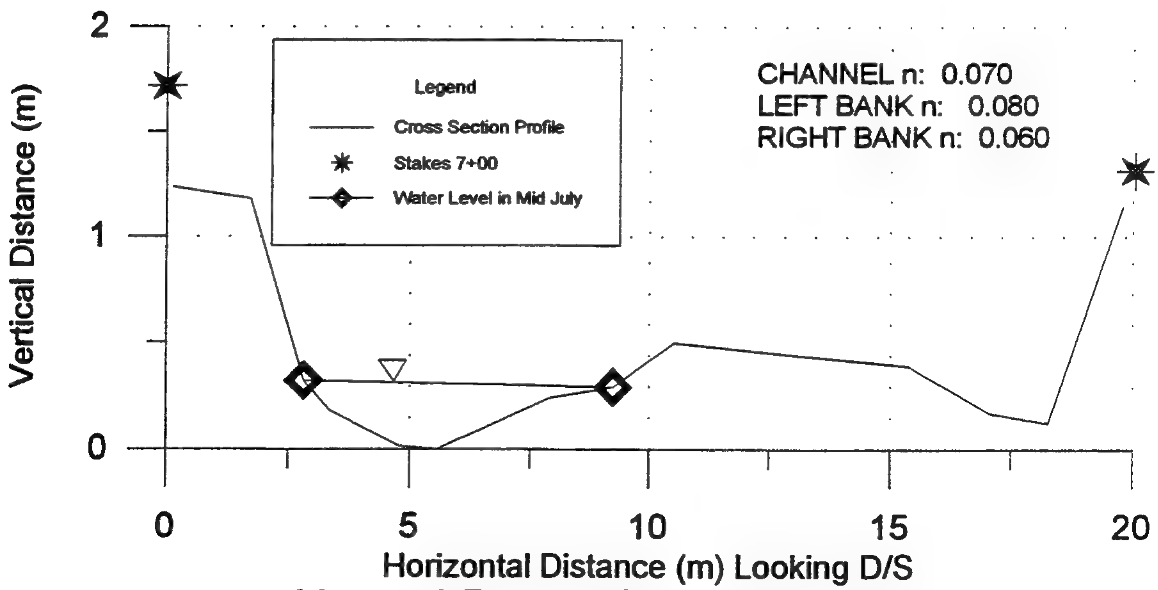
Natural Reach Cross Section N5



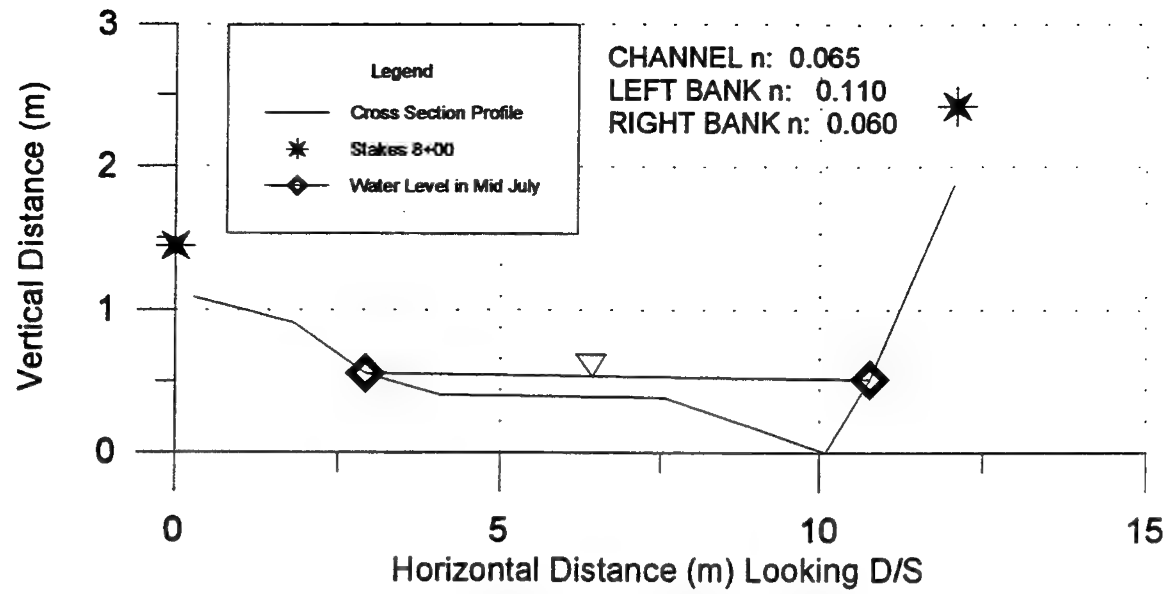
Natural Reach Cross Section N6



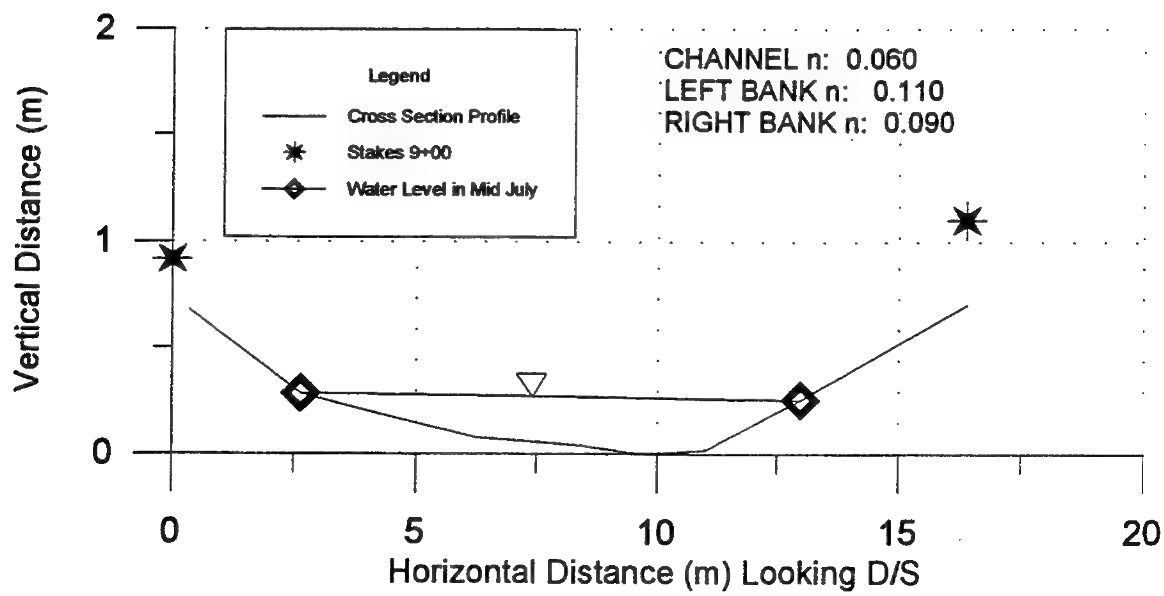
Natural Reach Cross Section N7



Natural Reach Cross Section N8

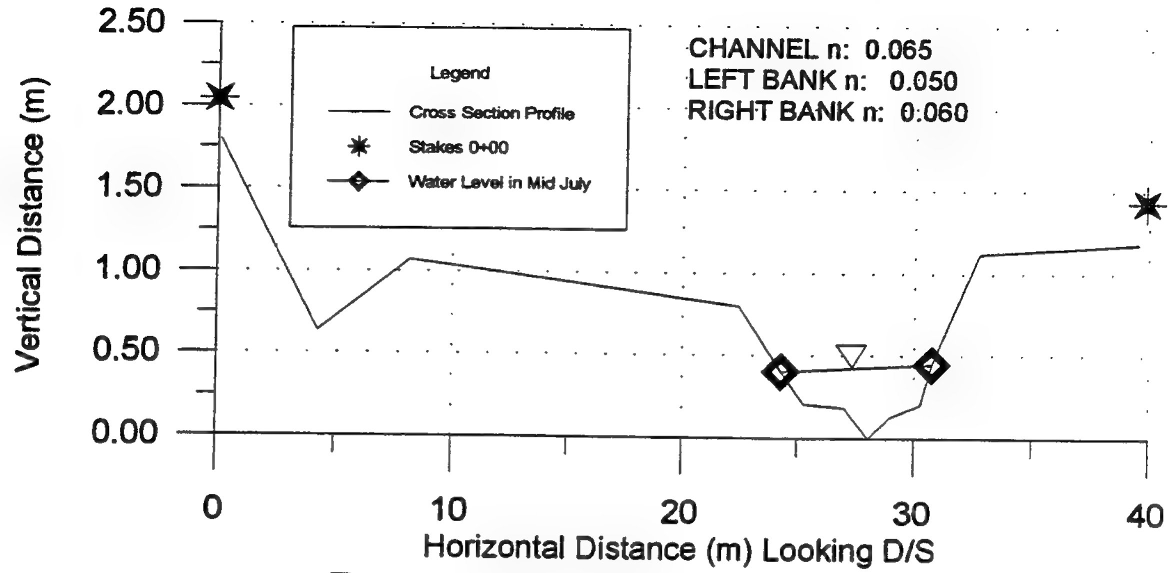


Natural Reach Cross Section N9

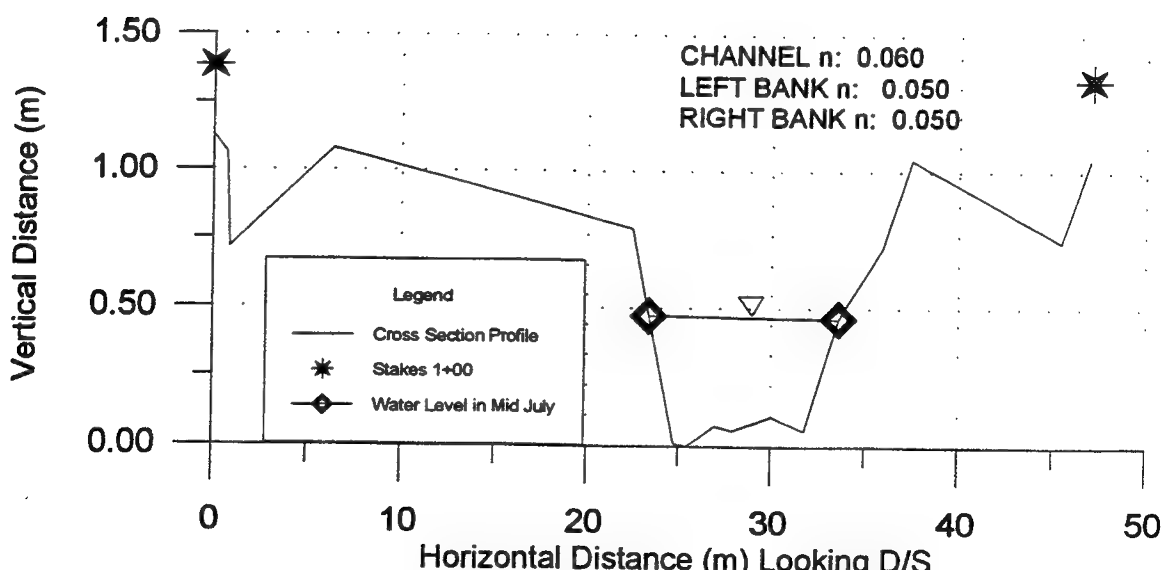


Natural Reach Cross Section N10

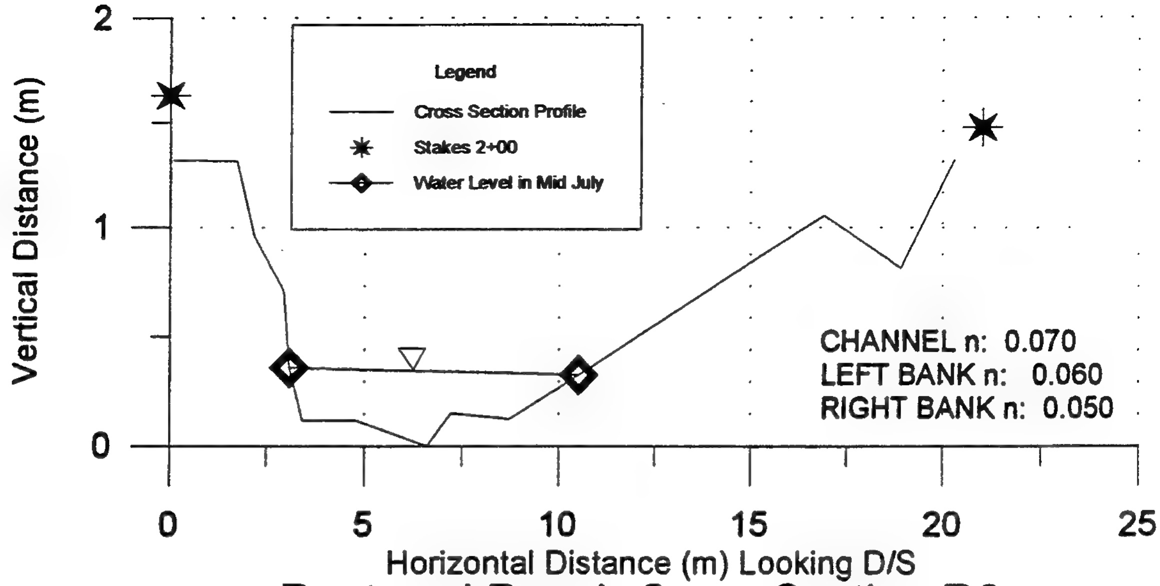
B.5 Cross Sections - Restored Reach



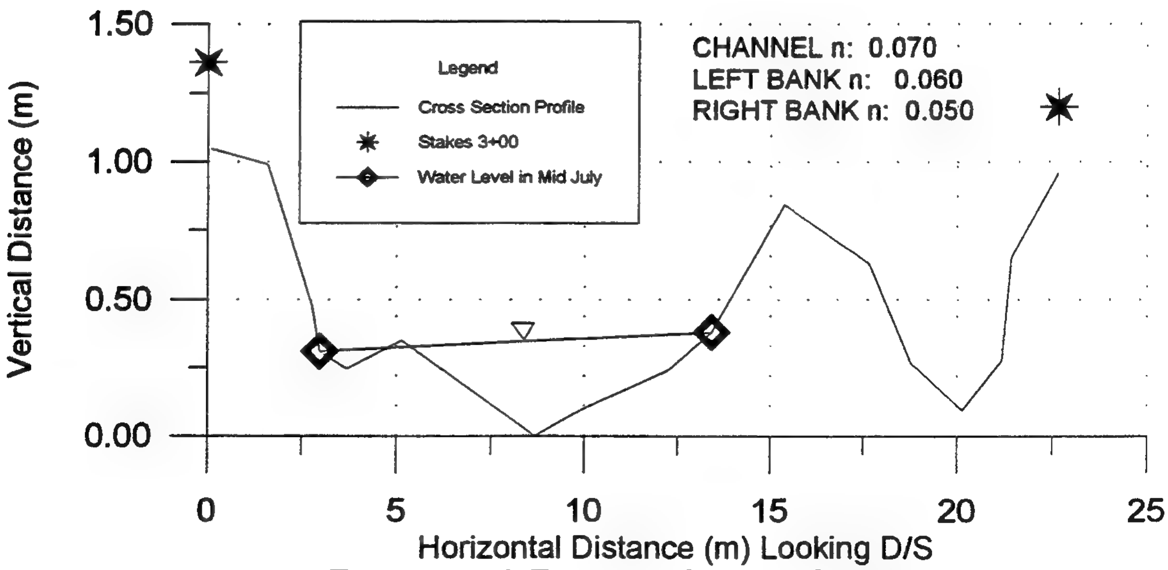
Restored Reach Cross Section R1



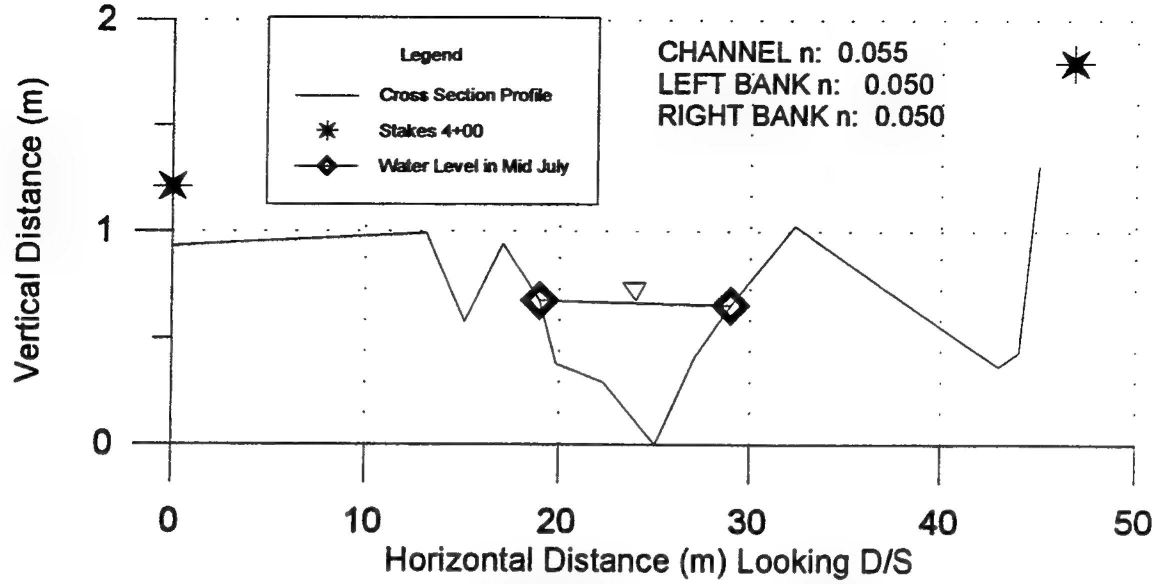
Restored Reach Cross Section R2



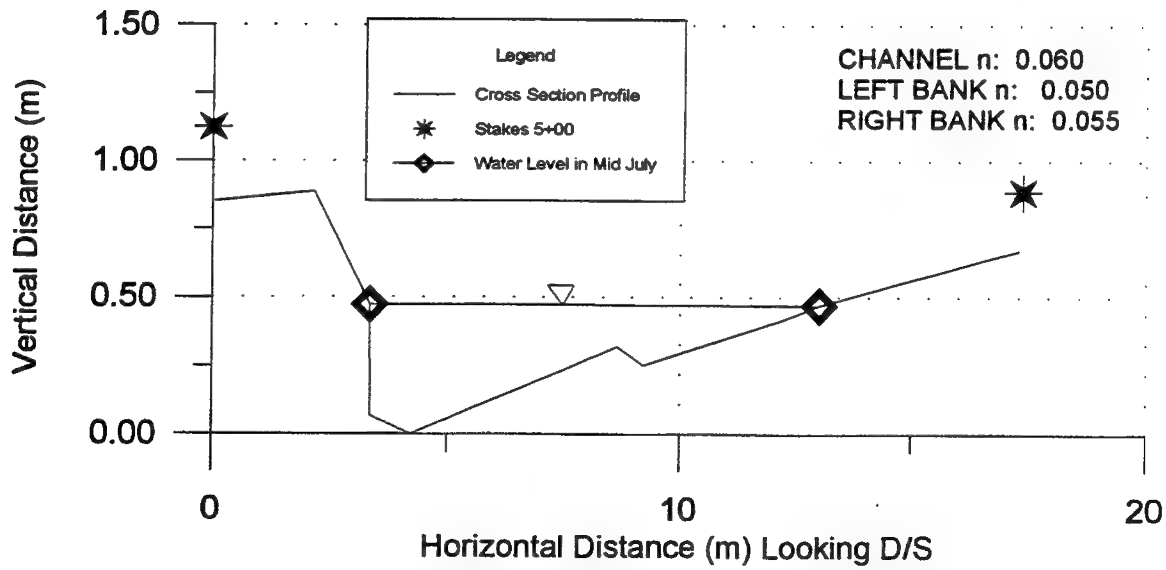
Restored Reach Cross Section R3



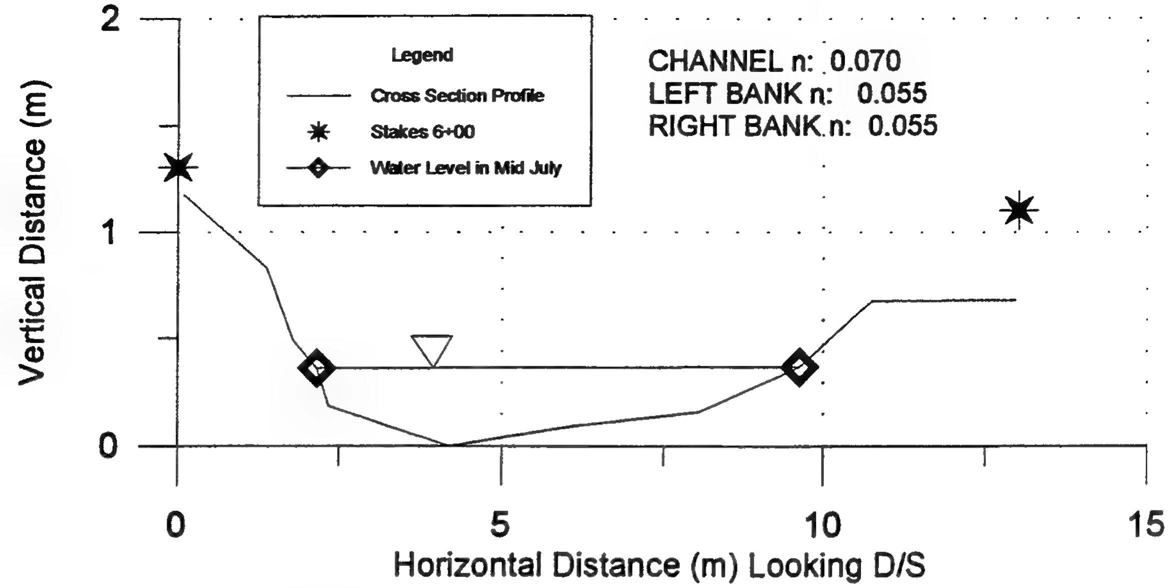
Restored Reach Cross Section R4



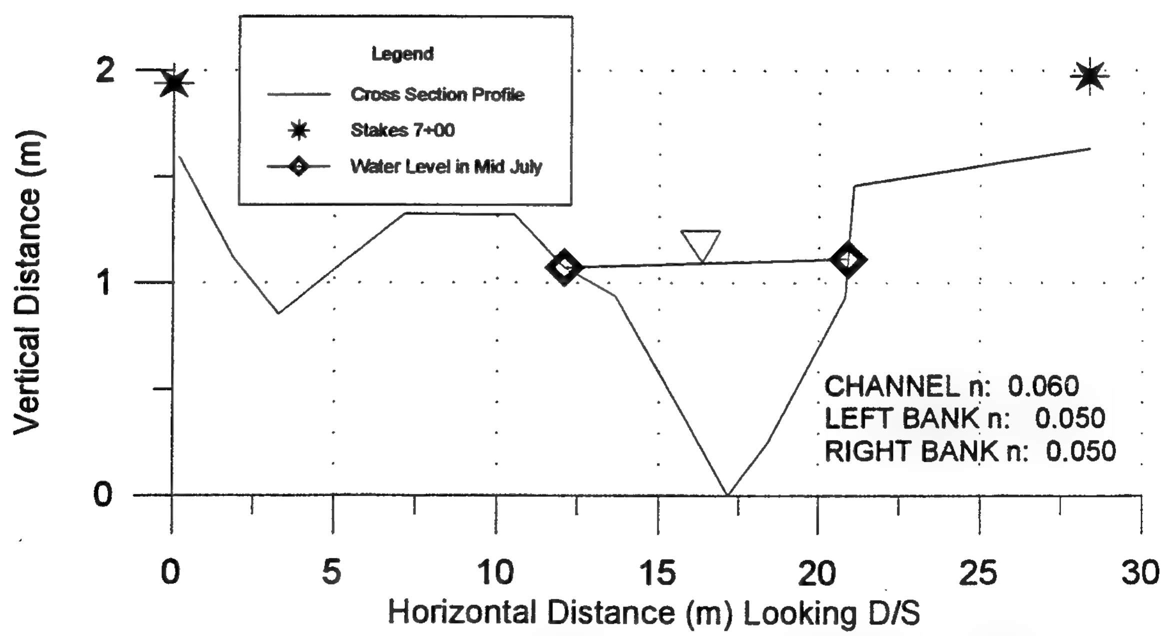
Restored Reach Cross Section R5



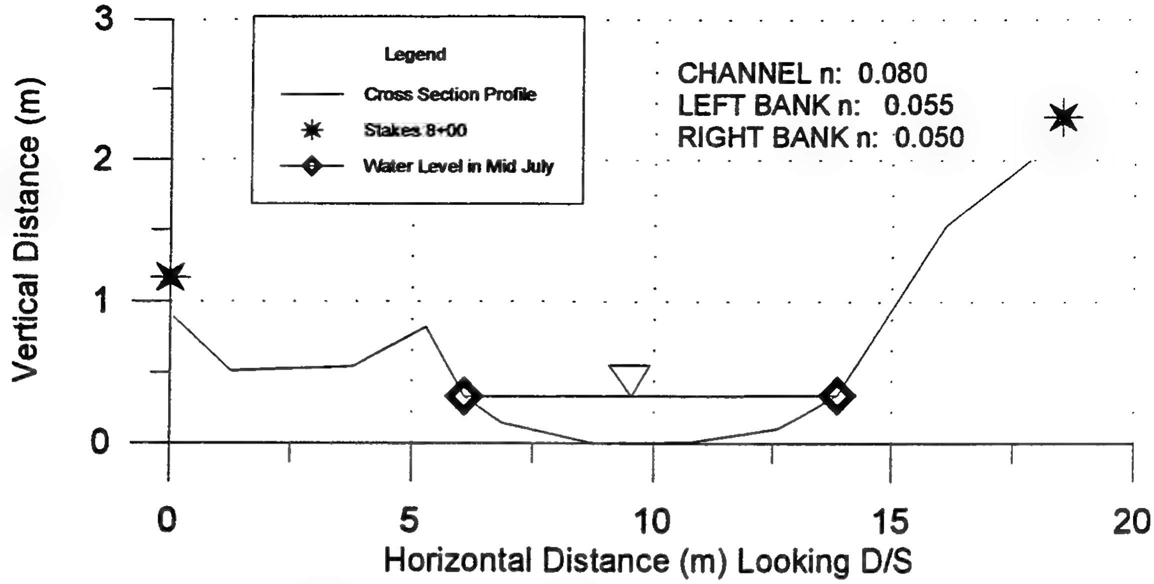
Restored Reach Cross Section R6



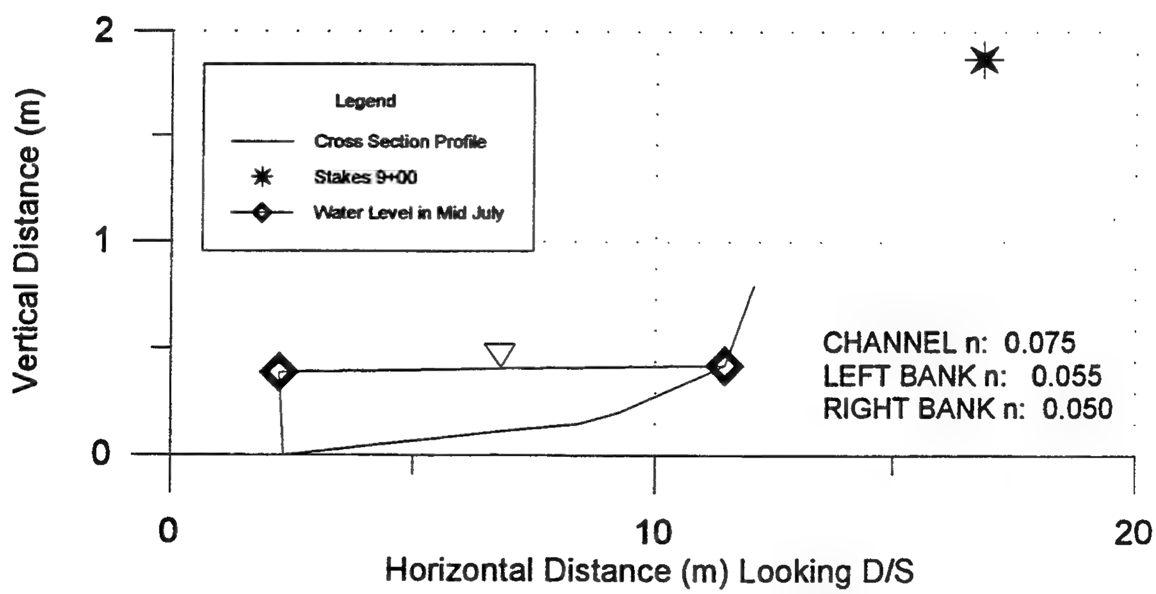
Restored Reach Cross Section R7



Restored Reach Cross Section R8

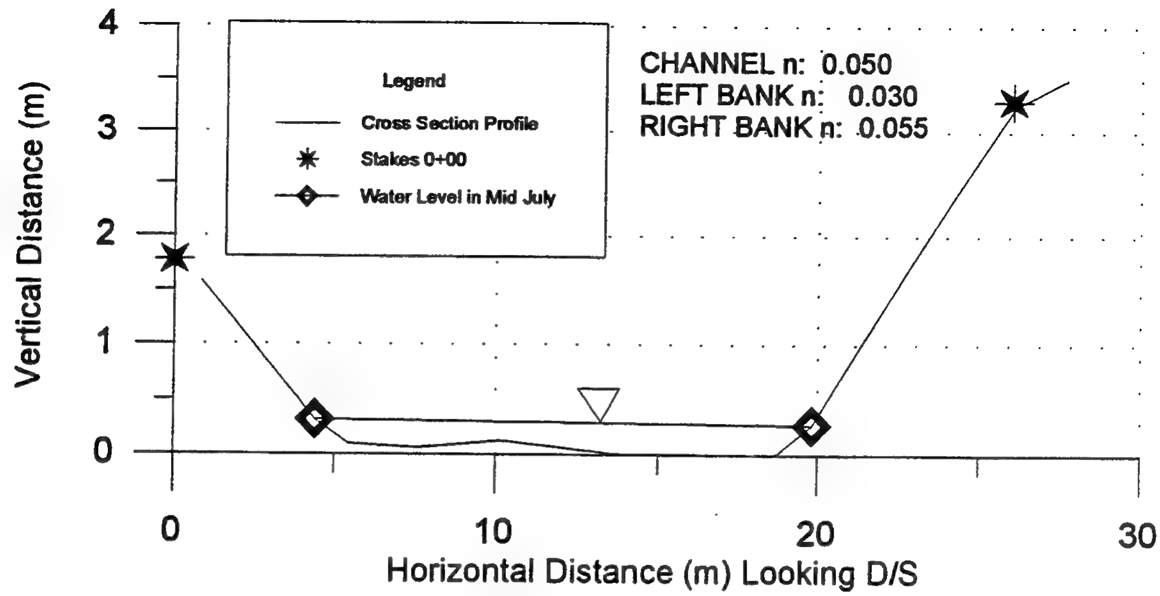


Restored Reach Cross Section R9

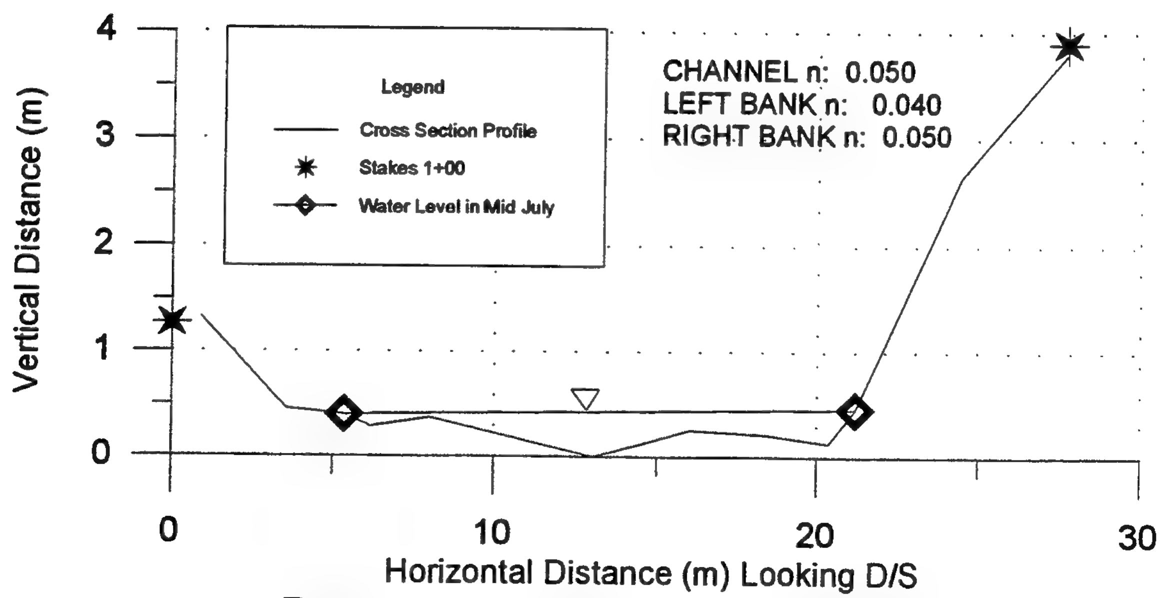


Restored Reach Cross Section R10

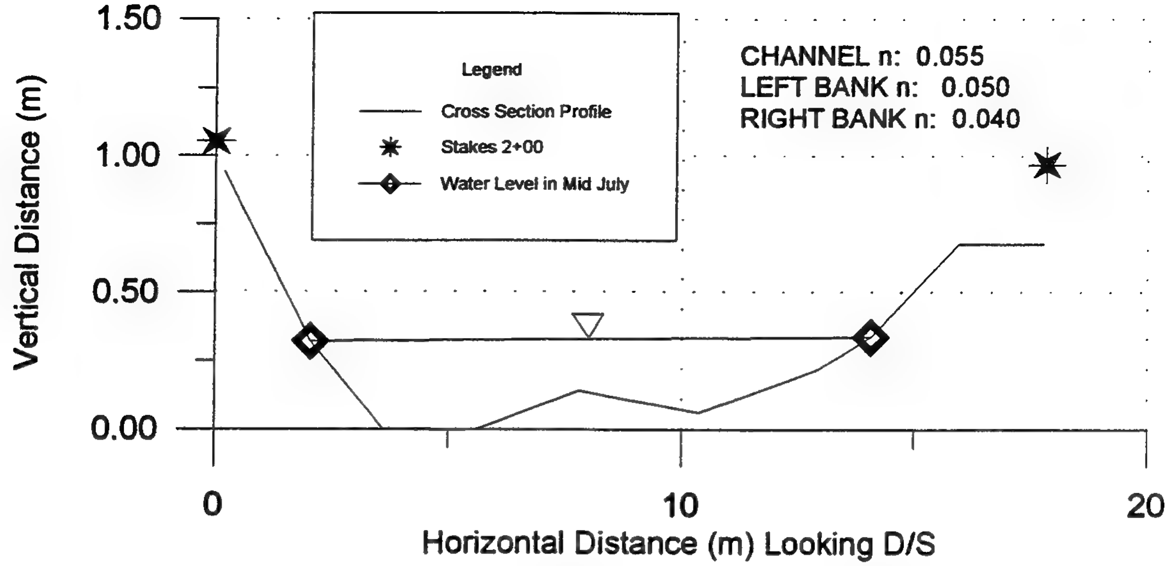
B.6 Cross Sections - Degraded Reach



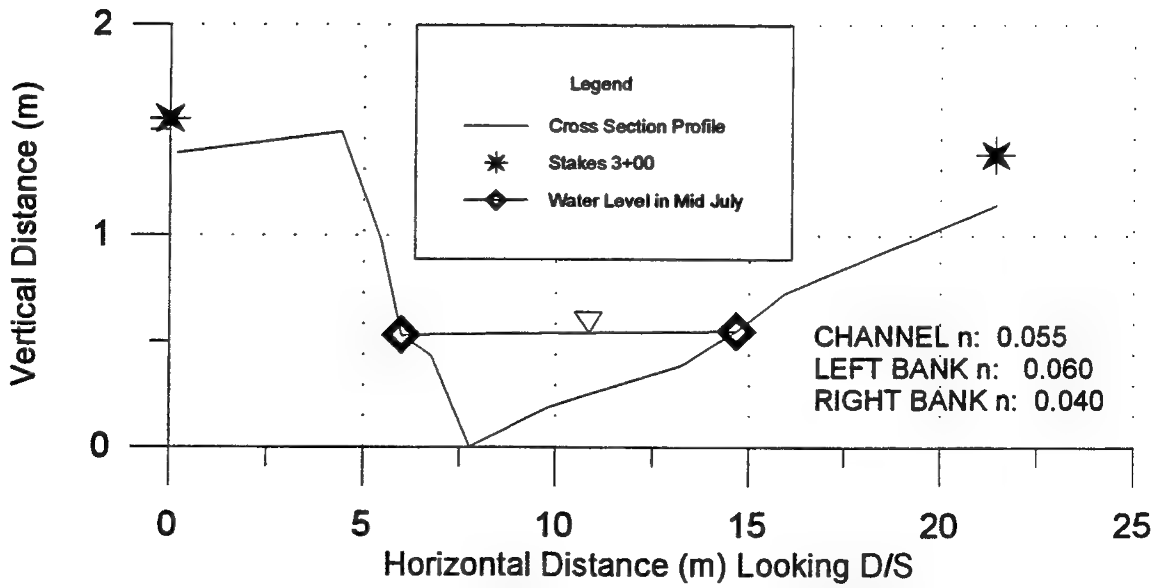
Degraded Reach Cross Section D1



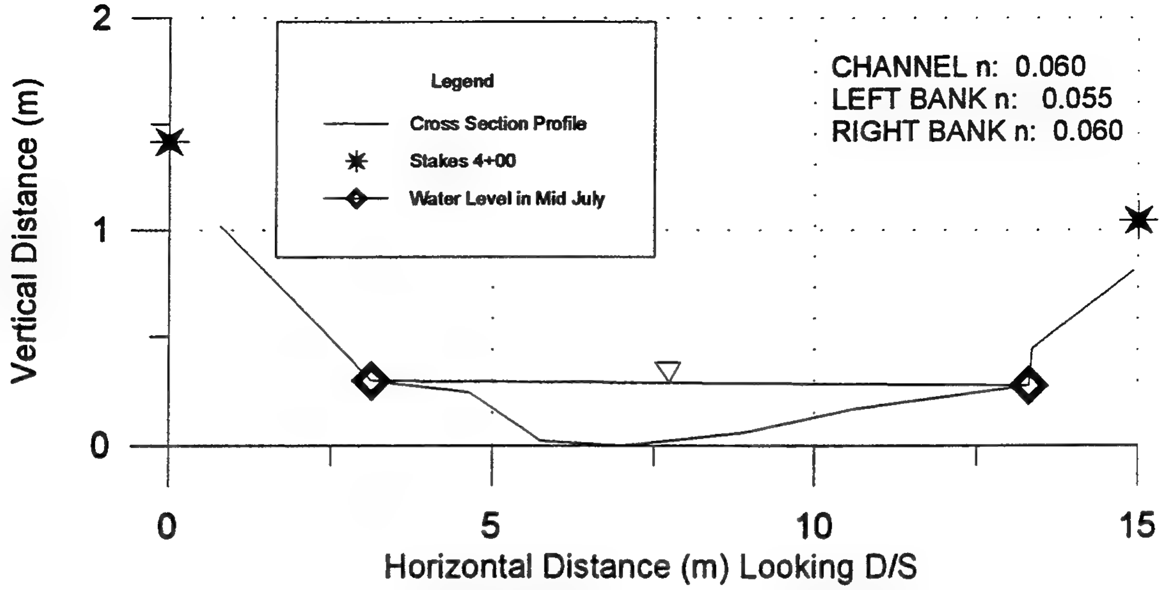
Degraded Reach Cross Section D2



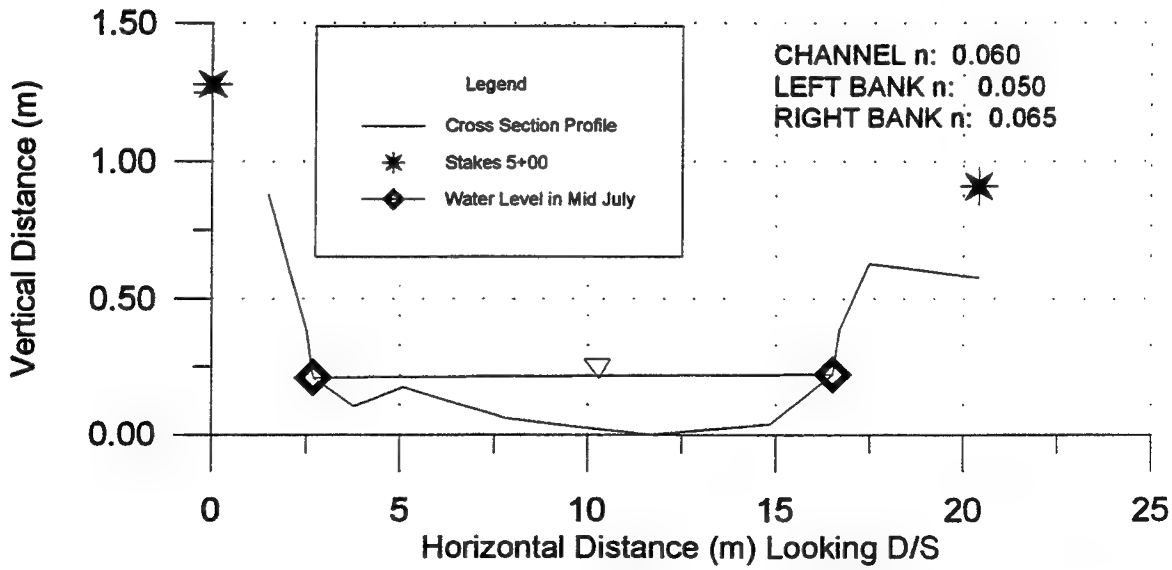
Degraded Reach Cross Section D3



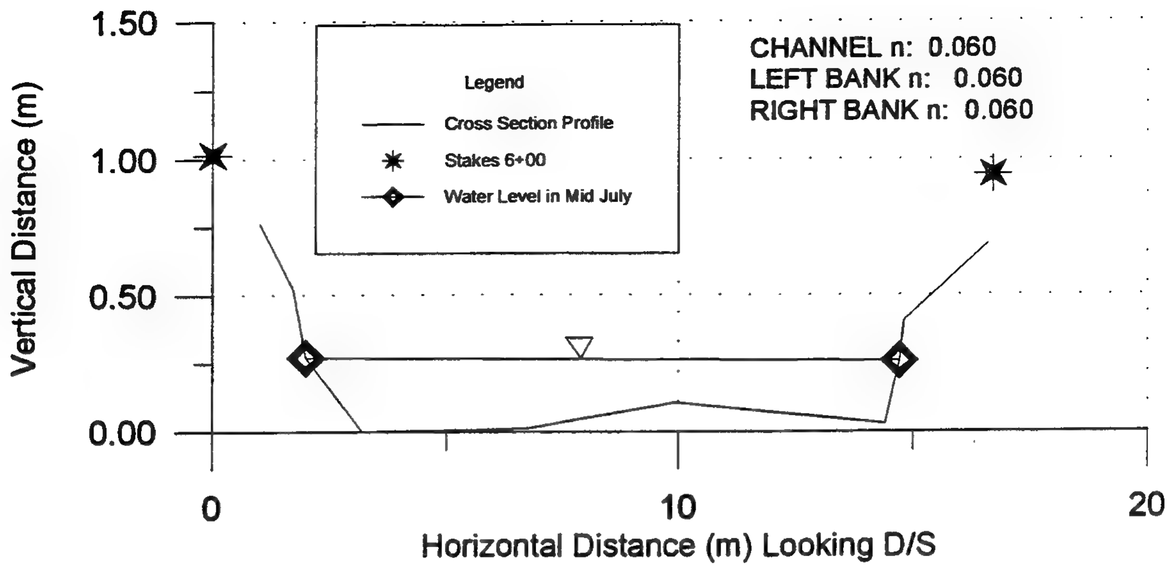
Degraded Reach Cross Section D4



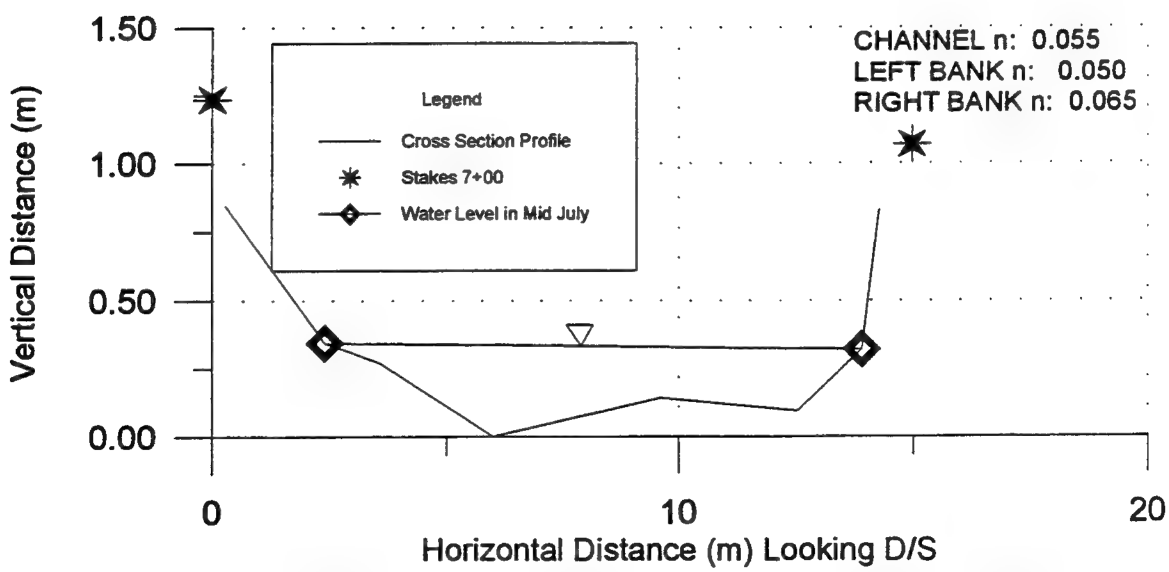
Degraded Reach Cross Section D5



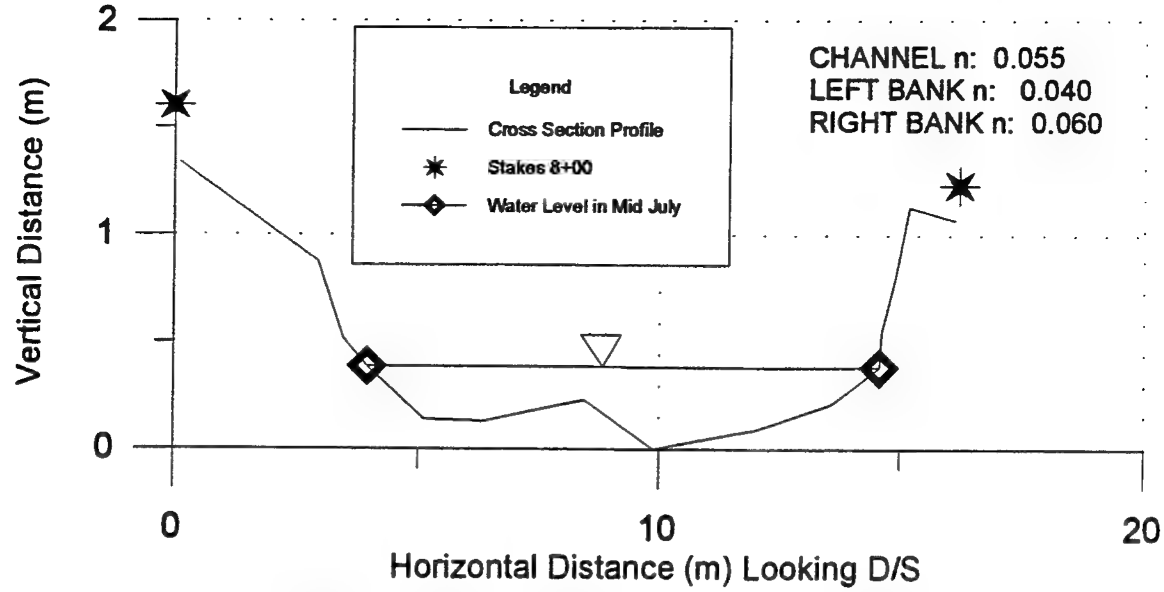
Degraded Reach Cross Section D6



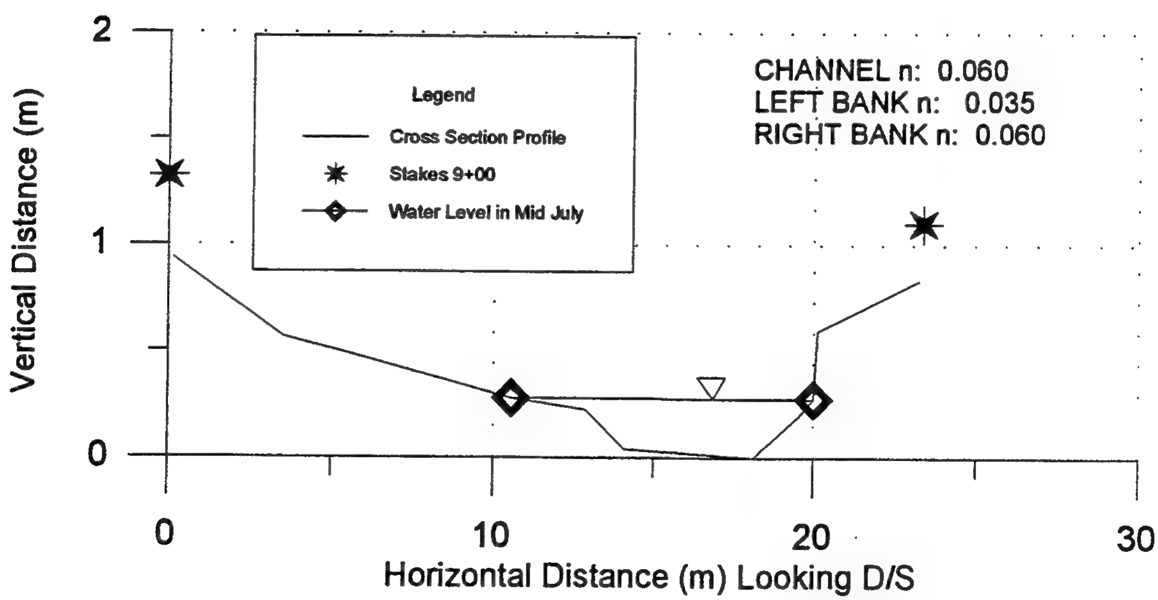
Degraded Reach Cross Section D7



Degraded Reach Cross Section D8



Degraded Reach Cross Section D9



Degraded Reach Cross Section D10

B.7 Bed Material - Natural Reach

Goose Creek July 94

Location Natural Section (Between Sections N5 and N6)
Description Armor
Performed By KLC

Grain Size Distribution

Mesh Size (mm)	Accumulated Weight Retained (g)	Percent Finer
203.2	0	100.00
152.400	6894.5	58.22
101.600	8370.5	49.28
76.200	13237.2	19.79
50.800	16434.6	0.41
38.100	16434.6	0.41
25.400	16503.0	0.00
19.050	16503.0	0.00
16.000	16503.0	0.00
8.000	16503.0	0.00
5.600	16503.0	0.00
4.000	16503.0	0.00
2.000	16503.0	0.00
1.000	16503.0	0.00
0.500	16503.0	0.00
0.250	16503.0	0.00
0.125	16503.0	0.00
0.063	16503.0	0.00
Pan	16503.0	0.00

Total Weight: 16503.0

Goose Creek July 94

Location Natural Section (Between Sections N5 and N6)
Description Substrate
Performed By KLC

Grain Size Distribution

Mesh Size (mm)	Accumulated Weight Retained - Tot. (g)	Percent Finer
203.2	0.0	100.00
152.400	6240.5	88.66
101.600	27896.2	49.31
76.200	30351.6	44.85
50.800	36724.2	33.27
38.100	39716.2	27.84
25.400	43140.3	21.62
19.050	44677.4	18.82
16.000	46036.2	16.36
8.000	49130.0	10.73
5.600	50429.4	8.37
4.000	51330.5	6.74
2.000	52941.9	3.81
1.000	54239.2	1.45
0.500	54827.6	0.38
0.250	54997.8	0.07
0.125	55023.8	0.03
0.063	55024.9	0.02
Pan	55038.1	0.00

Total Weight: 55038.1

B.8 Bed Material - Restored Reach

Goose Creek July 94

Location Restored Section (Between Sections R3 and R4)
Description Armor
Performed By KLC

Grain Size Distribution

Mesh Size (mm)	Accumulated Weight Retained (g)	Percent Finer
203.2	0	100.00
152.400	0.0	100.00
101.600	0.0	100.00
76.200	5114.4	54.42
50.800	9664.0	13.88
38.100	10986.0	2.10
25.400	11204.1	0.16
19.050	11213.0	0.08
16.000	11219.9	0.02
8.000	11220.9	0.01
5.600	11221.3	0.00
4.000	11221.6	0.00
2.000	11221.6	0.00
1.000	11221.6	0.00
0.500	11221.6	0.00
0.250	11221.6	0.00
0.125	11221.6	0.00
0.063	11221.6	0.00
Pan	11221.6	0.00

Total Weight: 11221.6

Goose Creek July 94

Location Restored Section (Between Sections R3 and R4)
Description Substrate
Performed By KLC

Grain Size Distribution

Mesh Size (mm)	Accumulated Weight Retained - Tot. (g)	Percent Finer
203.2	0.0	100.00
152.400	0.0	100.00
101.600	5943.4	81.66
76.200	5943.4	81.66
50.800	12269.8	62.13
38.100	16298.7	49.69
25.400	19675.8	39.27
19.050	22052.9	31.93
16.000	23233.3	28.29
8.000	26405.7	18.50
5.600	27542.3	14.99
4.000	28371.4	12.43
2.000	29865.5	7.82
1.000	31157.2	3.83
0.500	31983.9	1.28
0.250	32307.3	0.28
0.125	32378.9	0.06
0.063	32381.0	0.06
Pan	32399.5	0.00

Total Weight: 32399.5

B.9 Bed Material - Degraded Reach

Goose Creek July 94

Location Degraded Section (Between Sections D3 and D4)
Description Armor
Performed By KLC

Grain Size Distribution

Mesh Size (mm)	Accumulated Weight Retained (g)	Percent Finer
152.400	0.0	100.00
101.600	4775.7	67.58
76.200	7973.2	45.87
50.800	12552.2	14.78
38.100	14024.5	4.79
25.400	14641.5	0.60
19.050	14703.7	0.18
16.000	14727.6	0.01
8.000	14728.5	0.01
5.600	14729.1	0.00
4.000	14729.3	0.00
2.000	14729.5	0.00
1.000	14729.5	0.00
0.500	14729.5	0.00
0.250	14729.5	0.00
0.125	14729.5	0.00
0.063	14729.5	0.00
Pan	14729.5	0.00

Total Weight: 14729.5

Goose Creek July 94

Location Degraded Section (Between Sections D3 and D4)
Description Substrate
Performed By KLC

Grain Size Distribution

Mesh Size (mm)	Accumulated Weight Retained - Tot. (g)	Percent Finer
152.400	0.0	100.00
101.600	4600.0	84.43
76.200	5637.3	80.92
50.800	10861.9	63.24
38.100	15172.9	48.66
25.400	19178.4	35.10
19.050	20773.7	29.70
16.000	21722.9	26.49
8.000	24384.6	17.48
5.600	25409.9	14.02
4.000	26246.6	11.18
2.000	27669.3	6.37
1.000	28476.9	3.64
0.500	28851.0	2.37
0.250	29318.5	0.79
0.125	29488.3	0.21
0.063	29526.4	0.09
Pan	29551.6	0.00

Total Weight: 29551.6

Appendix C
Samples of Input and Output for HEC-2 and IFG4 and Input for RCHARC

C.1 Typical HEC-2 Input and Output

Typical HEC-2 Input

```
T1     Goose Creek 1994
T2     Surveyed July 1994

J1    0     2     0     0     0     0     0     0  96.45
J2    0     0

NH    3   .11   3.99  .065  42.93   .11 111.37
QT    1  27.8
X1    1    22     0  55.01     0     0     0
GR 97.50     0  97.1  3.99  96.25  4.98  96.48  13.45  95.94  16.09
GR 96.29 21.42 95.99 26.38  95.67 33.26  95.21  38.53  95.53  42.79
GR 96.44 42.791 97.75 42.93 98.03 55.01  96.48  55.29  97.11  61.57
GR 97.80 62.74 98.87 73.60  96.86 77.17  96.75  95.71  96.10 100.82
GR 97.13 106.40 102.17 111.37

NH    3   .09 14.94   .06  31.82   .09  36.71
X1    2    14     0  36.71  76.29 133.20  82.72
GR 99.71     0 99.76 11.48  98.41 14.94  96.92  16.12  95.75  16.20
GR 95.09 21.01 95.66 24.05  95.35 26.94  95.84  28.92  96.80  29.75
GR 96.93 31.06 97.20 31.82  98.67 32.91  98.60  36.71

NH    3   .11 18.59   .12  42.81   .11  48.13
X1    3    12     0  48.13  82.15 89.60  88.83
GR100.94     0 100.68 18.59 99.17 21.54  98.59  23.35  98.31  26.55
GR 98.14 29.86 98.40 33.37  98.28 35.85  99.17  39.94 100.09  42.25
GR101.92 42.81 102.63 48.13

NH    3   .10  5.23  .065  35.59   .08  40.56
X1    4    10     0  40.56  95.22 101.22 96.55
GR103.23     0 103.31  5.23 100.96  6.58 100.35  8.62  99.95  14.50
GR 99.95 17.53 100.73 24.42 101.09 29.69 102.32 35.59 102.41  40.56

NH    3   .11  4.03   .12  36.55   .06  61.07
X1    5    12     0  61.07  75.20 71.19  71.24
GR106.13     0 106.16  4.03 103.76  6.54 102.13  8.88 100.81  12.12
GR100.80 14.89 101.38 17.84 101.70 26.78 101.92 31.21 102.40  32.75
GR105.19 36.55 105.27 61.07
```

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NH    3   .05  10.63   .13  43.00   .06  57.62
X1    6    13      0  57.62  92.20 107.00  99.12
GR105.23      0 104.17  10.63 102.12  18.15 102.50  20.58 102.14  24.60
GR102.87  28.95 102.67  34.66 104.07  40.57 104.57  43.00 104.28  46.16
GR105.93  54.35 106.66  55.07 106.72  57.62

NH    3   .05  19.34   .07  77.75   .08  81.77
X1    7    14      0  81.71 104.79  93.85  99.51
GR128.47      0 110.74  19.34 108.17  21.30 107.87  29.02 107.44  35.76
GR107.91  39.74 107.61  45.60 107.52  50.08 107.92  54.53 108.34  67.14
GR108.03  71.61 108.47  73.55 112.03  77.75 113.61  81.71

NH    3   .08  15.57   .07  59.79   .06  64.76
X1    8    13      0  64.76 125.58  86.73 113.21
GR112.71      0 112.51   5.61 109.71   9.15 109.25  10.92 108.71  15.57
GR108.65  18.13 109.44  25.81 109.61  30.22 110.29  34.36 109.23  50.29
GR109.22  55.81 109.06  59.79 112.40  64.76

NH    2   .11   5.41  .100  39.09
X1    9     9      0  39.09  93.59 125.71 107.09
GR113.00      0 112.43   5.41 111.25   9.16 110.75  12.83 110.70  24.29
GR110.01  28.97 109.43  32.64 111.11  34.88 115.59  39.09

NH    3   .11   7.53   .06  41.49   .09  52.66
X1   10     9      0  52.66 111.51 129.49 125.00
GR114.81      0 113.52   7.53 113.26  11.72 112.84  19.37 112.71  26.43
GR112.58  30.37 112.64  35.00 113.42  41.49 114.89  52.66

EJ

ER
```

Typical HEC-2 Output

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST
*SECNO 1.000									
1.000	1.03	83.56	.00	83.56	83.57	.01	.00	.00	87.73
32.4	.0	32.4	.0	.0	40.8	.0	.0	.0	94.03
.00	.00	.79	.00	.000	.058	.000	.000	82.53	11.69
.001306	0.	0.	0.	0	0	0	.00	50.84	62.53
*SECNO 1.500									
1.500	1.67	83.58	.00	.00	83.59	.00	.02	.00	88.57
32.4	.0	32.4	.0	.0	59.8	.0	.0	.0	93.49
.01	.00	.54	.00	.000	.070	.000	.000	81.91	19.68
.000459	15.	23.	26.	0	0	0	.00	45.72	65.39
*SECNO 2.000									
2.000	.80	84.64	84.64	.00	84.80	.15	.20	.00	88.19
32.4	.0	32.4	.0	.0	10.3	.0	.1	.1	96.27
.02	.00	3.15	.00	.000	.070	.000	.000	83.84	34.79
.109094	110.	126.	134.	20	14	0	.00	34.03	70.71
*SECNO 2.300									
2.300	2.37	85.12	.00	.00	85.13	.01	.33	.00	88.39
32.4	.0	32.4	.0	.0	37.2	.0	.2	.2	96.58
.05	.00	.87	.00	.000	.070	.000	.000	82.75	39.56
.001362	73.	75.	72.	5	0	0	.00	31.29	70.85
*SECNO 2.600									
2.600	.89	85.69	85.69	.00	85.92	.23	.05	.00	88.58
32.4	.0	32.4	.0	.0	8.4	.0	.2	.2	96.39
.05	.00	3.84	.00	.000	.080	.000	.000	84.80	40.81
.126677	10.	11.	6.	20	22	0	.00	19.02	59.82
*SECNO 3.000									
3.000	1.08	87.14	.00	.00	87.16	.02	1.24	.00	89.15
32.4	.0	32.4	.0	.0	28.2	.0	.2	.3	88.28
.07	.00	1.15	.00	.000	.070	.000	.000	86.06	6.35
.004581	50.	96.	165.	4	0	0	.00	39.39	45.74
*SECNO 4.000									
4.000	1.69	87.49	.00	.00	87.52	.03	.37	.00	90.35
32.4	.0	32.4	.0	.0	22.1	.0	.3	.3	89.55
.09	.00	1.47	.00	.000	.053	.000	.000	85.80	19.42
.003691	91.	89.	83.	5	0	0	.00	27.11	46.53

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST
*SECNO 5.000									
5.000	.88	88.11	.00	.00	88.19	.08	.67	.00	90.58
32.4	.0	32.4	.0	.0	14.3	.0	.3	.4	89.88
.10	.00	2.26	.00	.000	.060	.000	.000	87.23	10.34
.022657	99.	89.	66.	3	0	0	.00	30.29	40.63
*SECNO 6.000									
6.000	.74	89.34	.00	.00	89.37	.03	1.18	.00	91.49
32.4	.0	32.4	.0	.0	22.4	.0	.3	.5	90.49
.12	.00	1.45	.00	.000	.060	.000	.000	88.60	3.93
.008761	97.	89.	81.	4	0	0	.00	45.47	49.40
*SECNO 7.000									
7.000	.82	90.20	.00	.00	90.23	.02	.85	.00	91.90
32.4	.0	32.4	.0	.0	26.6	.0	.4	.6	91.64
.14	.00	1.22	.00	.000	.080	.000	.000	89.38	3.58
.007884	104.	103.	94.	3	0	0	.00	41.44	45.01
*SECNO 8.000									
8.000	1.11	90.71	.00	.00	90.74	.03	.51	.00	92.37
32.4	.0	32.4	.0	.0	24.9	.0	.5	.7	92.33
.16	.00	1.30	.00	.000	.055	.000	.000	89.60	7.28
.004045	93.	93.	92.	2	0	0	.00	37.63	44.91
*SECNO 9.000									
9.000	1.30	91.00	.00	.00	91.02	.02	.28	.00	94.10
32.4	.0	32.4	.0	.0	27.4	.0	.5	.7	93.21
.18	.00	1.18	.00	.000	.065	.000	.000	89.70	12.80
.003731	75.	72.	70.	2	0	0	.00	34.96	47.75
*SECNO 10.000									
10.000	.66	91.82	91.74	.00	91.97	.15	.95	.00	94.23
32.4	.0	32.4	.0	.0	10.4	.0	.5	.8	93.90
.18	.00	3.12	.00	.000	.080	.000	.000	91.16	42.41
.074138	98.	96.	93.	13	14	0	.00	21.42	63.83

C.2 Typical IFG4 Input and Output

Typical IFG4 Input

```
Goose Creek
IFG4
IOC     11000001000110001 10 0
QARD  27.8
XSEC  1.0     0.0   .50    44.88   .01019
```

```
1.0   0.0    47.5   3.99   47.1   4.98   46.25  13.45  46.48  15.85  45.88  16.09  45.94
1.0   17.05  46.18  18.05  46.18  20.05  46.18  21.25  46.08  21.42  46.29  23.55  46.13
1.0   25.05  46.03  26.35  45.88  26.38  45.99  28.55  46.08  30.05  45.88  32.05  45.88
1.0   33.26  45.67  33.55  45.58  35.05  45.38  36.55  45.28  38.45  44.98  38.53  45.21
1.0   39.55  44.88  41.05  45.28  42.55  45.38  42.65  46.48  42.79  46.44  42.79  45.53
1.0   42.93  47.75  55.01  48.03  55.29  46.48  61.57  47.11  62.74  47.8   73.6   48.87
1.0   77.17  46.86  95.71  46.75  100.8  64.1   106.4  47.13  111.4  52.17
NS    1.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    1.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    1.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    1.0 1.00 1.00 1.00 1.00 1.00 0.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    1.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    1.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    1.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
WSL   1.0   46.45
CAL1  1.0   46.45   27.80
VEL1  1.0        0.00 0.00 .33 .39 0.00 0.00 .41 .47 .47 .41
VEL1  1.0 .59 1.00 1.01 2.19 .75 1.04 2.24 1.90 2.65 2.63 1.71 1.65
VEL1  1.0 1.87 .85 0.00 0.00 0.00
VEL1  1.0
XSEC  2.0    82.7   .50   44.92   .00304
2.0   0.0    49.71  11.46  49.76  14.94  48.41  16.12  46.92  16.2   45.75  16.52  46.02
2.0   17.42  46.72  18.62  46.72  19.62  46.12  20.12  45.12  20.62  44.92  21.01  45.09
2.0   21.47  45.02  22.62  45.22  23.62  45.22  24.05  45.66  24.52  45.32  25.62  45.72
2.0   26.62  45.42  26.94  45.35  27.37  45.42  28.52  45.42  28.92  45.84  29.52  45.72
2.0   29.75  46.8   30.12  46.52  30.62  46.72  31.06  46.93  31.52  46.92  31.82  47.2
2.0   32.91  48.67  36.71  48.6
NS    2.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    2.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    2.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    2.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    2.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    2.0 1.00 1.00 1.00 1.00
WSL   2.0   46.87
CAL1  2.0   46.87   27.80
VEL1  2.0         0.00 .01 .01 .10 .01 .02 .05 .52 1.31
VEL1  2.0 1.98 1.46 1.15 1.95 2.71 2.44 2.15 1.63 1.24 .99 .94 .90
VEL1  2.0 .98 1.03 1.10 0.00 0.00
XSEC  3.0   88.83 .50   48.14   .28197
3.0   0.0    50.94  18.59  50.68  21.54  49.17  22.64  48.82  23.35  48.59  23.54  48.57
3.0   24.64  48.77  25.64  48.27  26.55  48.31  26.84  48.17  27.64  48.27  28.64  48.47
3.0   29.86  48.14  29.94  48.17  30.64  48.17  31.64  48.32  32.64  48.37  33.37  48.4
3.0   33.49  48.27  34.64  48.22  35.85  48.28  35.99  48.42  36.34  48.27  36.64  49.17
3.0   37.64  49.17  39.14  48.97  39.64  49.17  39.94  49.17  42.25  50.09  42.81  51.92
3.0   48.13  52.63
NS    3.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    3.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    3.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    3.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    3.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    3.0 1.00 1.00
WSL   3.0   48.83
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CAL1  3.0    48.83    27.80
VEL1  3.0         0.00  .01  .01 0.00 0.00 2.04 2.25 2.94 1.81 2.66
VEL1  3.0 2.60 1.58 3.76 2.80 3.33 3.43 4.07 3.40 3.24 1.77 1.34 1.63
VEL1  3.0 0.00  .05 0.00
XSEC  4.0    96.55 .50    49.76    .00744
4.0    0.0    53.23   5.23   53.31   6.58   50.96   8.28   50.36   8.62   50.35   9.28   50.36
4.0    10.78  50.26   12.18  50.06   13.08  49.96   14.33  50.06   14.5   49.95   15.28  49.96
4.0    16.28  49.76   17.48  50.01   17.53  49.95   18.28  50.26   19.28  50.26   20.28  50.41
4.0    21.28  50.76   22.28  50.46   23.28  50.66   24.08  50.56   24.42  50.73   25.28  50.96
4.0    26.28  50.86   27.28  50.86   28.28  50.86   29.28  50.96   29.69  51.09   35.59  52.32
4.0    40.56  52.41
NS    4.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    4.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    4.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    4.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    4.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    4.0 1.00 1.00
WSL   4.0    51.15
CAL1  4.0    51.15    27.80
VEL1  4.0         0.00 0.00 0.00 0.00 0.00 0.00  .54 1.74 1.70 1.69
VEL1  4.0 2.00 2.70 1.05  .94 1.81 2.08 2.37 1.72 1.09 4.61 2.73 1.98
VEL1  4.0 1.78 1.91 1.45 0.00 0.00
XSEC  5.0    71.24 .50    50.43    .034794
5.0    0.0    56.13   4.03   56.16   6.54   53.76   8.88   52.13   9.88   51.53   10.88  51.13
5.0    11.98  50.83   12.12  50.81   12.88  50.73   13.88  50.43   14.88  50.88   14.89  50.8
5.0    15.88  51.23   16.88  51.28   17.78  51.53   17.84  51.38   18.88  51.48   19.88  51.33
5.0    20.88  51.53   22.38  51.43   23.38  51.63   24.38  51.63   25.38  51.73   26.78  51.7
5.0    26.78  51.83   27.88  51.63   29.88  51.63   31.18  51.83   31.21  51.92   32.75  52.4
5.0    32.88  52.13   36.55  55.19   61.07  55.27
NS    5.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    5.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    5.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    5.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    5.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    5.0 1.00 1.00 1.00 1.00 1.00 1.00
WSL   5.0    52.13
CAL1  5.0    52.13    27.80
VEL1  5.0         0.00 1.38  .77  .70  .82  .84 3.77 3.36 2.97
VEL1  5.0 2.96 3.20 1.62 2.27 2.31 1.35 1.50 2.29 2.60 2.08 2.33 2.33
VEL1  5.0 2.03  .40  .48  .16 0.00
XSEC  6.0    99.12 .50    52.07    .008821
6.0    0.0    55.23   10.63  54.17   13.13  52.92   15.13  52.52   16.63  52.47   17.98  52.07
6.0    18.15  52.12   19.03  52.22   20.43  52.47   20.58  52.5    21.63  52.32   22.93  52.37
6.0    24.53  52.17   24.6   52.14   25.63  52.27   26.93  52.37   28.73  52.87   28.95  52.87
6.0    29.93  52.72   31.33  52.77   33.03  52.67   34.53  52.77   34.66  52.67   36.03  53.07
6.0    37.63  53.42   39.13  53.67   40.43  54.17   40.57  54.07   43.0   54.57   46.16  54.28
6.0    54.35  55.93   55.07  56.66   57.62  56.72
NS    6.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    6.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    6.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    6.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    6.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS    6.0 1.00 1.00 1.00 1.00 1.00 1.00
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WSL  6.0    53.71
CAL1 6.0    53.71   27.80
VEL1 6.0     0.00 0.00 -.38 -.22 .06 .45 .53 .75 1.07 1.11 1.34
VEL1 6.0 1.58 1.55 1.55 1.97 1.43 1.02 .94 .21 .20 .19 .09 .08
VEL1 6.0 -.10 -.09 0.00
XSEC 7.0    99.51 .50    57.37  .113241
7.0    0.0    78.47  19.34  60.74  21.3   58.17  22.3   57.77  26.2   57.87  29.02  57.87
7.0    29.2   57.77  32.6   57.37  35.5   57.37  35.76  57.44  37.6   57.37  39.74  57.91
7.0    39.9   57.67  42.0   57.47  43.4   57.67  45.6   57.61  45.8   57.67  48.3   57.87
7.0    50.08  57.52  50.15  57.42  52.2   57.67  54.53  57.92  54.6   57.67  55.2   57.77
7.0    57.2   57.52  59.2   57.67  61.2   57.87  61.7   58.17  66.5   58.17  67.14  58.34
7.0    71.61  58.03  73.55  58.47  77.75  62.03  81.71  63.61
NS   7.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   7.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   7.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   7.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   7.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   7.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
WSL  7.0    58.02
CAL1 7.0    58.02   27.80
VEL1 7.0        0.00 0.00 0.00 .04 .74 .85 1.50 1.33 1.31 1.31
VEL1 7.0 1.37 .59 .60 .79 2.84 2.38 2.33 1.21 1.59 1.62 2.63 3.09
VEL1 7.0 .99 1.97 1.27 .11 0.00
XSEC 8.0    113.2 .50    58.65   .00566
8.0    0.0    62.71  5.61   62.51  9.15   59.71  10.65  59.11  10.92  59.25  11.65  59.01
8.0    12.65  58.91  13.65  58.81  14.65  58.71  15.35  58.91  15.57  58.71  16.65  58.91
8.0    17.65  58.81  18.13  58.65  18.15  58.76  19.15  58.81  20.15  58.81  21.15  58.81
8.0    22.15  58.91  23.15  59.01  24.15  59.21  25.65  59.21  25.81  59.44  26.65  59.41
8.0    27.65  59.41  28.65  59.51  30.15  59.71  30.22  59.61  34.36  60.29  50.29  59.93
8.0    55.81  59.22  59.79  59.06  64.76  62.4
NS   8.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   8.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   8.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   8.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   8.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   8.0 1.00 1.00 1.00 1.00 1.00 1.00
WSL  8.0    59.86
CAL1 8.0    59.86   27.80
VEL1 8.0        0.00 0.00 .45 .61 .22 1.32 1.88 1.10 1.79 1.93
VEL1 8.0 2.25 2.18 .52 1.84 3.45 3.88 3.09 3.28 2.35 3.39 2.38 2.20
VEL1 8.0 .93 1.31 0.00 0.00
XSEC 9.0    107.0 .50    59.43   .03640
9.0    0.0    63.0   5.41   62.43  9.16   61.25  10.16  60.95  11.16  60.85  12.16  60.55
9.0    12.66  60.65  12.83  60.75  13.66  60.65  14.66  60.55  15.66  60.55  16.66  60.45
9.0    17.66  60.45  18.66  60.45  19.66  60.85  20.66  60.75  21.66  60.95  23.66  60.85
9.0    24.29  60.7   25.16  60.85  27.16  60.45  28.96  60.3   28.97  60.01  30.66  59.75
9.0    32.64  59.43  32.66  59.45  34.16  61.25  34.88  61.11  39.09  65.59
NS   9.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   9.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   9.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   9.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   9.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
WSL  9.0    61.06
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CAL1  9.0    61.06    27.80
VEL1  9.0         0.00 2.05  .85  .81  .40 1.96 2.28 1.10 2.63 2.85
VEL1  9.0  .58 3.04 3.06  .28 1.93 1.26 1.58 1.82 2.47 1.55  .99  .99
VEL1  9.0  .99 1.08 0.00
XSEC  10.0    125.0 .50    62.42    .01135
10.0   0.0    64.81   7.53   63.52   9.03   63.32   10.53   63.02   11.72   63.26   12.03   63.22
10.0   13.53  63.02   15.03  62.92   16.53  62.92   18.03   62.72   19.37   62.84   19.53   62.72
10.0   21.03  62.92   22.53  62.92   24.03  62.82   25.53   62.62   26.43   62.71   27.03   62.42
10.0   28.53  62.62   30.37  62.58   30.53  62.57   32.03   62.62   33.03   62.92   34.53   62.62
10.0   35.0   62.64   35.23  62.92   37.03  63.12   39.03   62.72   40.53   63.32   41.49   63.42
10.0   42.03  63.52   52.66  64.89
NS   10.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   10.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   10.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   10.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   10.0 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
NS   10.0 1.00 1.00 1.00 1.00
WSL  10.0    63.41
CAL1 10.0    63.41    27.80
VEL1 10.0     0.00  .78  .82  .87 1.06 1.60 2.06 2.27 1.85 1.91 2.41
VEL1 10.0 1.09 1.58 2.64 1.88 1.71 1.45 1.69 1.66 1.27 1.51  .53  .70
VEL1 10.0  .62  .47 1.26  .82 0.00
ENDJ
□
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Typical IFG4 Output

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Goose Creek  PROGRAM-IFG4
07.52.30.                                IFG4

Physical Habitat Simulation System
National Ecology Research Center
Riverine and Wetland Ecosystems Branch
Program:  IFG4     Version  2.5
Last Modified: 92/02/26

IOC =  1 1 0 0 0 0 0 1 0 0 0 1 1 0 0 0 1 0 1 0
```

COMPUTATIONAL DETAILS FOR CROSS SECTION 1.00

CALCULATED DISCHARGE	26.3
WATER SURFACE ELEVATIONS	46.45
GIVEN DISCHARGE	27.8
WATERS EDGE AT LEFT	4.7
WATERS EDGE AT RIGHT	42.8
THE FUNCTION USED TO FIT S VS. Q IS:	S=A*Q**B+SZF

WHERE:
A= 0.000000E+00
B= 0.000000E+00
SZF= 0.448800E+02

VERTICAL	X	N	DEPTH	AREA	VELOCITY
2	4.0	0.10	0.0	0.00	
3	5.0	1.000	0.10	0.7	0.05
4	13.4	0.28	0.6	0.00	
5	15.9	0.313	0.54	0.1	0.35
6	16.1	0.246	0.39	0.4	0.41
7	17.0	1.000	0.27	0.3	0.07
8	18.0	1.000	0.27	0.5	0.07
9	20.0	0.153	0.32	0.4	0.43
10	21.2	0.164	0.26	0.0	0.49
11	21.4	0.094	0.24	0.5	0.49
12	23.5	0.171	0.37	0.6	0.43
13	25.0	0.143	0.50	0.6	0.62
14	26.4	0.103	0.51	0.0	1.05
15	26.4	0.089	0.41	0.9	1.06
16	28.5	0.035	0.47	0.7	2.30
17	30.0	0.138	0.57	1.1	0.79
18	32.0	0.099	0.68	0.8	1.09
19	33.3	0.057	0.83	0.2	2.35
20	33.5	0.072	0.97	1.5	1.99
21	35.0	0.059	1.12	1.7	2.78
22	36.5	0.064	1.32	2.5	2.76
23	38.5	0.114	1.36	0.1	1.79
24	38.5	0.105	1.41	1.4	1.73
25	39.5	0.109	1.37	2.1	1.96
26	41.0	0.197	1.12	1.7	0.89
27	42.5	1.000	0.53	0.1	0.17
28	42.7	0	0.01	0.0	0.00
29	42.8	1.000	0.47	0.0	0.01
30	42.8	1.000	0.46	0.0	0.15
31	42.9	0	0.00	0.0	0.00

COMPUTATIONAL DETAILS FOR CROSS SECTION 2.00

CALCULATED DISCHARGE	22.4
WATER SURFACE ELEVATIONS	46.87
GIVEN DISCHARGE	27.8
WATERS EDGE AT LEFT	16.1
WATERS EDGE AT RIGHT	30.9
THE FUNCTION USED TO FIT S VS. Q IS:	S=A*Q**B+SZF

WHERE:
A= 0.000000E+00
B= 0.000000E+00
SZF= 0.449200E+02

VERTICAL	X	N	DEPTH	AREA	VELOCITY
4	16.1	0.56	0.0	0.00	
5	16.2	8.863	0.98	0.3	0.01
6	16.5	7.368	0.50	0.4	0.01
7	17.4	0.230	0.15	0.2	0.12
8	18.6	2.305	0.45	0.4	0.01
9	19.6	3.388	1.25	0.6	0.02
10	20.1	2.390	1.85	0.9	0.06
11	20.6	0.247	1.86	0.7	0.65
12	21.0	0.092	1.81	0.8	1.63
13	21.5	0.063	1.75	2.0	2.46
14	22.6	0.079	1.65	1.6	1.81
15	23.6	0.100	1.43	0.6	1.43
16	24.0	0.048	1.38	0.6	2.42
17	24.5	0.041	1.35	1.5	3.37
18	25.6	0.037	1.30	1.3	3.03
19	26.6	0.049	1.49	0.5	2.67
20	26.9	0.067	1.49	0.6	2.03
21	27.4	0.085	1.45	1.7	1.54
22	28.5	0.106	1.24	0.5	1.23
23	28.9	0.089	1.09	0.7	1.17
24	29.5	0.100	0.61	0.1	1.12
25	29.7	0.014	0.21	0.1	1.22
26	30.1	0.039	0.25	0.1	1.28
27	30.6	0.021	0.07	0.0	1.37
28	31.1	0.00	0.0	0.00	

COMPUTATIONAL DETAILS FOR CROSS SECTION 3.00

CALCULATED DISCHARGE 17.1
WATER SURFACE ELEVATIONS 48.83
GIVEN DISCHARGE 27.8
WATERS EDGE AT LEFT 22.6
WATERS EDGE AT RIGHT 36.5
THE FUNCTION USED TO FIT S VS. Q IS: S=A*Q**B+SZF

WHERE:
A= 0.000000E+00
B= 0.000000E+00
SZF= 0.481400E+02

VERTICAL	X	N	DEPTH	AREA	VELOCITY
3	21.5		0.01	0.0	0.00
4	22.6	3.617	0.13	0.1	0.02
5	23.4	30.411	0.25	0.0	0.02
6	23.5	1.000	0.16	0.2	0.52
7	24.6	1.000	0.31	0.3	0.19
8	25.6	0.263	0.54	0.5	3.31
9	26.5	0.227	0.59	0.2	3.65
10	26.8	0.204	0.61	0.5	4.77
11	27.6	0.296	0.46	0.5	2.94
12	28.6	0.150	0.53	0.6	4.32
13	29.9	0.237	0.68	0.1	4.22
14	29.9	0.379	0.68	0.5	2.56
15	30.6	0.159	0.59	0.6	6.10
16	31.6	0.180	0.49	0.5	4.54
17	32.6	0.141	0.45	0.3	5.40
18	33.4	0.131	0.50	0.1	5.57
19	33.5	0.132	0.59	0.7	6.60
20	34.6	0.167	0.58	0.7	5.52
21	35.8	0.164	0.48	0.1	5.26
22	36.0	0.246	0.49	0.2	2.87
23	36.3	0.400	0.28	0.1	2.17
24	36.6		0.00	0.0	0.00

COMPUTATIONAL DETAILS FOR CROSS SECTION 4.00

CALCULATED DISCHARGE	20.8
WATER SURFACE ELEVATIONS	51.15
GIVEN DISCHARGE	27.8
WATERS EDGE AT LEFT	6.5
WATERS EDGE AT RIGHT	30.0
THE FUNCTION USED TO FIT S VS. Q IS:	S=A*Q**B+SZF

WHERE:
A= 0.000000E+00
B= 0.000000E+00
SZF= 0.497600E+02

VERTICAL	X	N	DEPTH	AREA	VELOCITY
2	5.2	0.10	0.0	0.00	
3	6.6	1.000	0.49	0.8	0.06
4	8.3	1.000	0.80	0.3	0.14
5	8.6	1.000	0.80	0.5	0.14
6	9.3	1.000	0.84	1.3	0.14
7	10.8	1.000	0.99	1.4	0.15
8	12.2	1.000	1.14	1.0	0.18
9	13.1	0.267	1.14	1.4	0.70
10	14.3	0.078	1.15	0.2	2.27
11	14.5	0.085	1.20	0.9	2.22
12	15.3	0.085	1.29	1.3	2.20
13	16.3	0.080	1.27	1.5	2.61
14	17.5	0.052	1.17	0.1	3.52
15	17.5	0.138	1.05	0.8	1.37
16	18.3	0.126	0.89	0.9	1.23
17	19.3	0.066	0.82	0.8	2.36
18	20.3	0.051	0.57	0.6	2.71
19	21.3	0.029	0.54	0.5	3.09
20	22.3	0.058	0.59	0.6	2.24
21	23.3	0.073	0.54	0.4	1.42
22	24.1	0.020	0.51	0.2	6.01
23	24.4	0.026	0.31	0.3	3.56
24	25.3	0.021	0.24	0.2	2.58
25	26.3	0.032	0.29	0.3	2.32
26	27.3	0.029	0.29	0.3	2.49
27	28.3	0.039	0.24	0.2	1.89
28	29.3	1.000	0.13	0.1	0.06
29	29.7	1.000	0.03	0.0	0.03
30	35.6	0.00	0.0	0.00	

COMPUTATIONAL DETAILS FOR CROSS SECTION 5.00

CALCULATED DISCHARGE	31.4
WATER SURFACE ELEVATIONS	52.13
GIVEN DISCHARGE	27.8
WATERS EDGE AT LEFT	8.9
WATERS EDGE AT RIGHT	32.9
THE FUNCTION USED TO FIT S VS. Q IS:	S=A*Q**B+SZF

WHERE:
A= 0.000000E+00
B= 0.000000E+00
SZF= 0.504300E+02

VERTICAL	X	N	DEPTH	AREA	VELOCITY
4	8.9	0.30	0.3	0.00	
5	9.9	0.143	0.80	0.8	1.22
6	10.9	0.361	1.15	1.3	0.68
7	12.0	0.473	1.31	0.2	0.62
8	12.1	0.408	1.36	1.0	0.72
9	12.9	0.415	1.55	1.6	0.74
10	13.9	0.105	1.48	1.5	3.33
11	14.9	0.096	1.29	0.0	2.97
12	14.9	0.113	1.12	1.1	2.63
13	15.9	0.087	0.88	0.9	2.62
14	16.9	0.078	0.73	0.7	2.83
15	17.8	0.122	0.68	0.0	1.43
16	17.8	0.101	0.70	0.7	2.01
17	18.9	0.090	0.73	0.7	2.04
18	19.9	0.177	0.70	0.7	1.19
19	20.9	0.132	0.65	1.0	1.33
20	22.4	0.096	0.60	0.6	2.02
21	23.4	0.067	0.50	0.5	2.30
22	24.4	0.084	0.45	0.5	1.84
23	25.4	0.065	0.42	0.6	2.06
24	26.8	0.068	0.36	0.0	2.06
25	26.8	0.061	0.40	0.4	1.79
26	27.9	0.437	0.50	1.0	0.35
27	29.9	0.364	0.40	0.5	0.42
28	31.2	0.775	0.26	0.0	0.14
29	31.2	1.000	0.11	0.1	0.09
30	32.7	0.00	0.0	0.00	
31	32.9	0.00	0.0	0.00	
32	36.5	0.00	0.0	0.00	

COMPUTATIONAL DETAILS FOR CROSS SECTION 6.00

CALCULATED DISCHARGE	19.8
WATER SURFACE ELEVATIONS	53.71
GIVEN DISCHARGE	27.8
WATERS EDGE AT LEFT	11.5
WATERS EDGE AT RIGHT	39.2
THE FUNCTION USED TO FIT S VS. Q IS:	S=A*Q**B+SZF

WHERE:
A= 0.000000E+00
B= 0.000000E+00
SZF= 0.520700E+02

VERTICAL	X	N	DEPTH	AREA	VELOCITY
2	10.6	0.40	0.6	0.00	
3	13.1	1.000	0.99	2.0	0.17
4	15.1	-0.414	1.21	1.8	-0.53
5	16.6	-0.735	1.44	1.9	-0.31
6	18.0	3.249	1.61	0.3	0.08
7	18.1	0.424	1.54	1.4	0.63
8	19.0	0.345	1.36	1.9	0.74
9	20.4	0.216	1.22	0.2	1.05
10	20.6	0.149	1.30	1.4	1.49
11	21.6	0.157	1.36	1.8	1.55
12	22.9	0.127	1.44	2.3	1.87
13	24.5	0.118	1.56	0.1	2.21
14	24.6	0.122	1.50	1.6	2.16
15	25.6	0.115	1.39	1.8	2.16
16	26.9	0.086	1.09	2.0	2.75
17	28.7	0.087	0.84	0.2	2.00
18	29.0	0.122	0.91	0.9	1.42
19	29.9	0.148	0.96	1.4	1.31
20	31.3	0.639	0.99	1.7	0.29
21	33.0	0.718	0.99	1.5	0.28
22	34.5	0.707	0.99	0.1	0.27
23	34.7	1.596	0.84	1.2	0.13
24	36.0	1.297	0.47	0.7	0.11
25	37.6	-0.611	0.17	0.2	-0.14
26	39.1	-0.180	0.02	0.0	-0.13
27	40.4	0.00	0.0	0.00	

COMPUTATIONAL DETAILS FOR CROSS SECTION 7.00

CALCULATED DISCHARGE	17.7
WATER SURFACE ELEVATIONS	58.02
GIVEN DISCHARGE	27.8
WATERS EDGE AT LEFT	21.7
WATERS EDGE AT RIGHT	61.5
THE FUNCTION USED TO FIT S VS. Q IS:	S=A*Q**B+SZF

WHERE:
A= 0.000000E+00
B= 0.000000E+00
SZF= 0.573700E+02

VERTICAL	X	N	DEPTH	AREA	VELOCITY
3	21.3	0.12	0.1	0.00	
4	22.3	1.000	0.20	0.8	0.31
5	26.2	1.000	0.15	0.4	0.22
6	29.0	3.517	0.20	0.0	0.06
7	29.2	0.268	0.45	1.5	1.15
8	32.6	0.442	0.65	1.9	1.32
9	35.5	0.250	0.62	0.2	2.33
10	35.8	0.262	0.62	1.1	2.07
11	37.6	0.287	0.38	0.8	2.03
12	39.7	0.087	0.23	0.0	2.03
13	39.9	0.181	0.45	0.9	2.13
14	42.0	0.569	0.45	0.6	0.92
15	43.4	0.414	0.38	0.8	0.93
16	45.6	0.349	0.38	0.1	1.23
17	45.8	0.087	0.25	0.6	4.41
18	48.3	0.059	0.33	0.6	3.70
19	50.1	0.135	0.55	0.0	3.62
20	50.2	0.294	0.48	1.0	1.88
21	52.2	0.156	0.23	0.5	2.47
22	54.5	0.066	0.23	0.0	2.52
23	54.6	0.094	0.30	0.2	4.08
24	55.2	0.064	0.37	0.7	4.80
25	57.2	0.318	0.43	0.9	1.54
26	59.2	0.126	0.25	0.5	3.06
27	61.2	0.111	0.08	0.0	1.97
28	61.7	0.00	0.0	0.00	

COMPUTATIONAL DETAILS FOR CROSS SECTION 8.00

CALCULATED DISCHARGE	31.7
WATER SURFACE ELEVATIONS	59.86
GIVEN DISCHARGE	27.8
WATERS EDGE AT LEFT	9.0
WATERS EDGE AT RIGHT	61.0
THE FUNCTION USED TO FIT S VS. Q IS:	S=A*Q**B+SZF

WHERE:
A= 0.000000E+00
B= 0.000000E+00
SZF= 0.586500E+02

VERTICAL	X	N	DEPTH	AREA	VELOCITY
2	5.6	0.08	0.0	0.00	
3	9.1	1.000	0.45	0.7	0.03
4	10.6	1.000	0.68	0.2	0.08
5	10.9	0.179	0.73	0.5	0.39
6	11.6	0.165	0.90	0.9	0.53
7	12.6	0.492	1.00	1.0	0.19
8	13.6	0.088	1.10	1.1	1.14
9	14.6	0.065	1.05	0.7	1.63
10	15.4	0.098	1.05	0.2	0.95
11	15.6	0.069	1.05	1.1	1.55
12	16.6	0.056	1.00	1.0	1.67
13	17.6	0.051	1.13	0.5	1.95
14	18.1	0.058	1.16	0.0	1.89
15	18.1	0.230	1.08	1.1	0.45
16	19.1	0.063	1.05	1.0	1.59
17	20.1	0.034	1.05	1.0	2.98
18	21.1	0.030	1.00	1.0	3.36
19	22.1	0.035	0.90	0.9	2.67
20	23.1	0.031	0.75	0.8	2.84
21	24.1	0.036	0.65	1.0	2.03
22	25.6	0.025	0.54	0.1	2.93
23	25.8	0.026	0.44	0.4	2.06
24	26.6	0.030	0.45	0.5	1.90
25	27.6	0.071	0.40	0.4	0.80
26	28.6	0.042	0.25	0.4	1.13
27	30.1	1.000	0.20	0.0	0.03
28	30.2	1.000	0.12	0.2	0.04
29	34.4	0.00	0.0	0.00	
30	50.3	0.32	1.6	0.00	
31	55.8	1.000	0.72	2.9	0.07
32	59.8	1.000	0.40	0.5	0.08
33	64.8	0.00	0.0	0.00	

COMPUTATIONAL DETAILS FOR CROSS SECTION 9.00

CALCULATED DISCHARGE	19.6
WATER SURFACE ELEVATIONS	61.06
GIVEN DISCHARGE	27.8
WATERS EDGE AT LEFT	9.8
WATERS EDGE AT RIGHT	34.0
THE FUNCTION USED TO FIT S VS. Q IS:	S=A*Q**B+SZF

WHERE:
A= 0.000000E+00
B= 0.000000E+00
SZF= 0.594300E+02

VERTICAL	X	N	DEPTH	AREA	VELOCITY
3	9.2	0.06	0.0	0.00	
4	10.2	0.032	0.16	0.2	2.90
5	11.2	0.118	0.36	0.4	1.20
6	12.2	0.224	0.46	0.2	1.15
7	12.7	0.391	0.36	0.1	0.57
8	12.8	0.066	0.36	0.3	2.78
9	13.7	0.069	0.46	0.5	3.23
10	14.7	0.165	0.51	0.5	1.56
11	15.7	0.069	0.56	0.6	3.72
12	16.7	0.072	0.61	0.6	4.04
13	17.7	0.352	0.61	0.6	0.82
14	18.7	0.067	0.41	0.4	4.30
15	19.7	0.033	0.26	0.3	4.33
16	20.7	0.463	0.21	0.2	0.40
17	21.7	0.034	0.16	0.3	2.73
18	23.7	0.079	0.29	0.2	1.78
19	24.3	0.091	0.29	0.2	2.24
20	25.2	0.055	0.41	0.8	2.58
21	27.2	0.083	0.69	1.2	3.50
22	29.0	0.153	0.91	0.0	2.19
23	29.0	0.297	1.18	2.0	1.40
24	30.7	0.344	1.47	2.9	1.40
25	32.6	0.398	1.62	0.0	1.40
26	32.7	0.362	0.81	1.1	1.53
27	34.2	0.00	0.0	0.00	

COMPUTATIONAL DETAILS FOR CROSS SECTION 10.00

CALCULATED DISCHARGE	26.1
WATER SURFACE ELEVATIONS	63.41
GIVEN DISCHARGE	27.8
WATERS EDGE AT LEFT	8.4
WATERS EDGE AT RIGHT	41.4
THE FUNCTION USED TO FIT S VS. Q IS:	S=A*Q**B+SZF

WHERE:
A= 0.000000E+00
B= 0.000000E+00
SZF= 0.624200E+02

VERTICAL	X	N	DEPTH	AREA	VELOCITY
2	7.5	0.05	0.0	0.00	
3	9.0	0.041	0.24	0.4	0.83
4	10.5	0.103	0.27	0.3	0.87
5	11.7	0.051	0.17	0.1	0.93
6	12.0	0.049	0.29	0.4	1.13
7	13.5	0.053	0.44	0.7	1.70
8	15.0	0.048	0.49	0.7	2.19
9	16.5	0.043	0.59	0.9	2.41
10	18.0	0.067	0.63	0.8	1.97
11	19.4	0.057	0.63	0.1	2.03
12	19.5	0.051	0.59	0.9	2.56
13	21.0	0.090	0.49	0.7	1.16
14	22.5	0.062	0.54	0.8	1.68
15	24.0	0.042	0.69	1.0	2.81
16	25.5	0.072	0.75	0.7	2.00
17	26.4	0.073	0.85	0.5	1.82
18	27.0	0.109	0.89	1.3	1.54
19	28.5	0.080	0.81	1.5	1.80
20	30.4	0.084	0.83	0.1	1.77
21	30.5	0.111	0.82	1.2	1.35
22	32.0	0.090	0.64	0.6	1.61
23	33.0	0.186	0.64	1.0	0.56
24	34.5	0.194	0.78	0.4	0.74
25	35.0	0.215	0.63	0.1	0.66
26	35.2	0.209	0.39	0.7	0.50
27	37.0	0.055	0.49	1.0	1.34
28	39.0	0.151	0.39	0.6	0.87
29	40.5	1.000	0.05	0.0	0.03
30	41.5	0.00	0.0	0.00	

C.3 Typical RCHARC Input

A	0	27.8	96.45		A	0.08	27.8	103.71	
B	4	0	0.1	0	B	10.6	0	0.4	0
B	5	4	0.1	0.05	B	13.1	10.6	0.99	0.17
B	13.4	5	0.28	0	B	15.1	13.1	1.21	-0.53
B	15.9	13.4	0.54	0.35	B	16.6	15.1	1.44	-0.31
B	16.1	15.9	0.39	0.41	B	18	16.6	1.61	0.08
B	17	16.1	0.27	0.07	B	18.1	18	1.54	0.63
B	18	17	0.27	0.07	B	19	18.1	1.36	0.74
B	20	18	0.32	0.43	B	20.4	19	1.22	1.05
B	21.2	20	0.26	0.49	B	20.6	20.4	1.3	1.49
B	21.4	21.2	0.24	0.49	B	21.6	20.6	1.36	1.55
B	23.5	21.4	0.37	0.43	B	22.9	21.6	1.44	1.87
B	25	23.5	0.5	0.62	B	24.5	22.9	1.56	2.21
B	26.4	25	0.51	1.05	B	24.6	24.5	1.5	2.16
B	26.4	26.4	0.41	1.06	B	25.6	24.6	1.39	2.16
B	28.5	26.4	0.47	2.3	B	26.9	25.6	1.09	2.75
B	30	28.5	0.57	0.79	B	28.7	26.9	0.84	2
B	32	30	0.68	1.09	B	29	28.7	0.91	1.42
B	33.3	32	0.83	2.35	B	29.9	29	0.96	1.31
B	33.5	33.3	0.97	1.99	B	31.3	29.9	0.99	0.29
B	35	33.5	1.12	2.78	B	33	31.3	0.99	0.28
B	36.5	35	1.32	2.76	B	34.5	33	0.99	0.27
B	38.5	36.5	1.36	1.79	B	34.7	34.5	0.84	0.13
B	38.5	38.5	1.41	1.73	B	36	34.7	0.47	0.11
B	39.5	38.5	1.37	1.96	B	37.6	36	0.17	-0.14
B	41	39.5	1.12	0.89	B	39.1	37.6	0.02	-0.13
B	42.5	41	0.53	0.17	B	40.4	39.1	0	0
B	42.7	42.5	0.01	0	A	0.1	27.8	108.2	
B	42.8	42.7	0.47	0.01	B	19.3	0	0	0
B	42.8	42.8	0.46	0.15	B	21.3	19.3	0.12	0
B	42.9	42.8	0	0	B	22.3	21.3	0.2	0.31
A	0.02	27.8	96.87		B	26.2	22.3	0.15	0.22
B	14.9	0	0	0	B	29	26.2	0.2	0.06
B	16.1	14.9	0.56	0	B	29.2	29	0.45	1.15
B	16.2	16.1	0.98	0.01	B	32.6	29.2	0.65	1.32
B	16.5	16.2	0.5	0.01	B	35.5	32.6	0.62	2.33
B	17.4	16.5	0.15	0.12	B	35.8	35.5	0.62	2.07
B	18.6	17.4	0.45	0.01	B	37.6	35.8	0.38	2.03
B	19.6	18.6	1.25	0.02	B	39.7	37.6	0.23	2.03
B	20.1	19.6	1.85	0.06	B	39.9	39.7	0.45	2.13
B	20.6	20.1	1.86	0.65	B	42	39.9	0.45	0.92
B	21	20.6	1.81	1.63	B	43.4	42	0.38	0.93

B	21.5	21	1.75	2.46	B	45.6	43.4	0.38	1.23
B	22.6	21.5	1.65	1.81	B	45.8	45.6	0.25	4.41
B	23.6	22.6	1.43	1.43	B	48.3	45.8	0.33	3.7
B	24	23.6	1.38	2.42	B	50.1	48.3	0.55	3.62
B	24.5	24	1.35	3.37	B	50.2	50.1	0.48	1.88
B	25.6	24.5	1.3	3.03	B	52.2	50.2	0.23	2.47
B	26.6	25.6	1.49	2.67	B	54.5	52.2	0.23	2.52
B	26.9	26.6	1.49	2.03	B	54.6	54.5	0.3	4.08
B	27.4	26.9	1.45	1.54	B	55.2	54.6	0.37	4.8
B	28.5	27.4	1.24	1.23	B	57.2	55.2	0.43	1.54
B	28.9	28.5	1.09	1.17	B	59.2	57.2	0.25	3.06
B	29.5	28.9	0.61	1.12	B	61.2	59.2	0.08	1.97
B	29.7	29.5	0.21	1.22	B	61.7	61.2	0	0
B	30.1	29.7	0.25	1.28	A	0.12	27.8	109.86	
B	30.6	30.1	0.07	1.37	B	5.6	0	0.08	0
B	31.1	30.6	0	0	B	9.1	5.6	0.45	0.03
A	0.03	27.8	98.83		B	10.6	9.1	0.68	0.08
B	18.59	0	0	0	B	10.9	10.6	0.73	0.39
B	21.5	18.59	0.01	0	B	11.6	10.9	0.9	0.53
B	22.6	21.5	0.13	0.02	B	12.6	11.6	1	0.19
B	23.4	22.6	0.25	0.02	B	13.6	12.6	1.1	1.14
B	23.5	23.4	0.16	0.52	B	14.6	13.6	1.05	1.63
B	24.6	23.5	0.31	0.19	B	15.4	14.6	1.05	0.95
B	25.6	24.6	0.54	3.31	B	15.6	15.4	1.05	1.55
B	26.5	25.6	0.59	3.65	B	16.6	15.6	1	1.67
B	26.8	26.5	0.61	4.77	B	17.6	16.6	1.13	1.95
B	27.6	26.8	0.46	2.94	B	18.1	17.6	1.16	1.89
B	28.6	27.6	0.53	4.32	B	18.1	18.1	1.08	0.45
B	29.9	28.6	0.68	4.22	B	19.1	18.1	1.05	1.59
B	29.9	29.9	0.66	2.56	B	20.1	19.1	1.05	2.98
B	30.6	29.9	0.59	6.1	B	21.1	20.1	1	3.36
B	31.6	30.6	0.49	4.54	B	22.1	21.1	0.9	2.67
B	32.6	31.6	0.45	5.4	B	23.1	22.1	0.75	2.84
B	33.4	32.6	0.5	5.57	B	24.1	23.1	0.65	2.03
B	33.5	33.4	0.59	6.6	B	25.6	24.1	0.54	2.93
B	34.6	33.5	0.58	5.52	B	25.8	25.6	0.44	2.06
B	35.8	34.6	0.48	5.26	B	26.6	25.8	0.45	1.9
B	36	35.8	0.49	2.87	B	27.6	26.6	0.4	0.8
B	36.3	36	0.28	2.17	B	28.6	27.6	0.25	1.13
B	36.6	36.3	0	0	B	30.1	28.6	0.2	0.03
A	0.05	27.8	101.15		B	30.2	30.1	0.12	0.04
B	5.2	0	0.1	0	B	34.4	30.2	0	0
B	6.6	5.2	0.49	0.06	B	50.3	34.4	0.32	0
B	8.3	6.6	0.8	0.14	B	55.8	50.3	0.72	0.07
B	8.6	8.3	0.8	0.14	B	59.8	55.8	0.4	0.08

B	9.3	8.6	0.84	0.14	B	64.8	59.8	0	0
B	10.8	9.3	0.99	0.15	A	0.14	27.8	111.06	
B	12.2	10.8	1.14	0.18	B	5.4	0	0	0
B	13.1	12.2	1.14	0.7	B	9.2	5.4	0.06	0
B	14.3	13.1	1.15	2.27	B	10.2	9.2	0.16	2.9
B	14.5	14.3	1.2	2.22	B	11.2	10.2	0.36	1.2
B	15.3	14.5	1.29	2.2	B	12.2	11.2	0.46	1.15
B	16.3	15.3	1.27	2.61	B	12.7	12.2	0.36	0.57
B	17.5	16.3	1.17	3.52	B	12.8	12.7	0.36	2.78
B	17.5	17.5	1.05	1.37	B	13.7	12.8	0.46	3.23
B	18.3	17.5	0.89	1.23	B	14.7	13.7	0.51	1.56
B	19.3	18.3	0.82	2.36	B	15.7	14.7	0.56	3.72
B	20.3	19.3	0.57	2.71	B	16.7	15.7	0.61	4.04
B	21.3	20.3	0.54	3.09	B	17.7	16.7	0.61	0.82
B	22.3	21.3	0.59	2.24	B	18.7	17.7	0.41	4.3
B	23.3	22.3	0.54	1.42	B	19.7	18.7	0.26	4.33
B	24.1	23.3	0.51	6.01	B	20.7	19.7	0.21	0.4
B	24.4	24.1	0.31	3.56	B	21.7	20.7	0.16	2.73
B	25.3	24.4	0.24	2.58	B	23.7	21.7	0.29	1.78
B	26.3	25.3	0.29	2.32	B	24.3	23.7	0.29	2.24
B	27.3	26.3	0.29	2.49	B	25.2	24.3	0.41	2.58
B	28.3	27.3	0.24	1.89	B	27.2	25.2	0.69	3.5
B	29.3	28.3	0.13	0.06	B	29	27.2	0.91	2.19
B	29.7	29.3	0.03	0.03	B	29	29	1.18	1.4
B	35.6	29.7	0	0	B	30.7	29	1.47	1.4
A	0.06	27.8	102.13		B	32.6	30.7	1.62	1.4
B	6.5	0	0	0	B	32.7	32.6	0.81	1.53
B	8.9	6.5	0.3	0	B	34.2	32.7	0	0
B	9.9	8.9	0.8	1.22	A	0.17	27.8	113.41	
B	10.9	9.9	1.15	0.68	B	7.5	0	0.05	0
B	12	10.9	1.31	0.62	B	9	7.5	0.24	0.83
B	12.1	12	1.36	0.72	B	10.5	9	0.27	0.87
B	12.9	12.1	1.55	0.74	B	11.7	10.5	0.17	0.93
B	13.9	12.9	1.48	3.33	B	12	11.7	0.29	1.13
B	14.9	13.9	1.29	2.97	B	13.5	12	0.44	1.7
B	14.9	14.9	1.12	2.63	B	15	13.5	0.49	2.19
B	15.9	14.9	0.88	2.62	B	16.5	15	0.59	2.41
B	16.9	15.9	0.73	2.83	B	18	16.5	0.63	1.97
B	17.8	16.9	0.68	1.43	B	19.4	18	0.63	2.03
B	17.8	17.8	0.7	2.01	B	19.5	19.4	0.59	2.56
B	18.9	17.8	0.73	2.04	B	21	19.5	0.49	1.16
B	19.9	18.9	0.7	1.19	B	22.5	21	0.54	1.68
B	20.9	19.9	0.65	1.33	B	24	22.5	0.69	2.81
B	22.4	20.9	0.6	2.02	B	25.5	24	0.75	2
B	23.4	22.4	0.5	2.3	B	26.4	25.5	0.85	1.82

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C. Bradley Florentin, Steven R. Abt, Chester C. Watson, Kent L. Collins, J. Craig Fischenich, John M. Nestler

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Civil Engineering, Colorado State University, Fort Collins, CO 80523;
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

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13. ABSTRACT *(Maximum 200 words)*

Aquatic habitat quality is dependent on water quality, bed slope, water temperature, dissolved oxygen, substrate, vegetation, and hydraulic parameters in the stream system. The Riverine Community Habitat Assessment and Restoration Concept (RCHARC) is a methodology developed by the U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory, to compare hydraulic parameters (depth and velocity) between natural, degraded, and restored channel reaches. The methodology is generally applied to alternative reaches in the same stream; therefore, the habitat quality variables must also be closely matched. RCHARC assumes that if the diversity of hydraulic and habitat quality parameters for a "comparison standard" reach can be replicated in the stream restoration reach, that the aquatic habitat quality can be enhanced. The RCHARC methodology has been successfully applied to large, warmwater rivers. The objective of this study was to Beta test the RCHARC methodology for its applicability to cool-water channels. In addition, the model was modified and again Beta tested to evaluate potential enhancements to the methodology.

The field site selected for testing the RCHARC methodology was Goose Creek, located near Wagon Wheel Gap, Colorado. Natural, degraded, and restored reaches were identified for comparison. Field crews were dispatched to collect field data during moderate flow conditions. Data collected included cross-sectional profiles, discharge,

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14. SUBJECT TERMS

Aquatic habitat	Fish	Habitat simulation
Channelization	Flood control	Streams
Channel stability	Habitat diversity	

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depth and velocity pairs, dissolved oxygen, water temperature, thalweg and water surface elevations profiles, suspended and bed load samples, armor layer and substrate samples, and photographic documentation.

The data were compiled, placed into a comprehensive database, and analyzed. A HEC-2 simulation was conducted to evaluate the flood-control capacity of each reach. Output from HEC-2 served as input to the RCHARC model. The RCHARC model was run comparing the cumulative frequency distribution of hydraulic depth and velocity pairs for the three combinations of reaches. The RCHARC output was plotted in the three dimensions of velocity versus depth versus frequency of occurrence. The bivariate plots of the comparison reaches were qualitatively and quantitatively evaluated for similarity at similar discharges. Canberra metric coefficients of dissimilarity were calculated for each set of comparisons. The reaches displayed minimal similarities.

The RCHARC simulation package was modified based upon the Beta analysis. The primary modifications included (a) removal of the empty data sets from the depth-velocity pairs analysis, (b) writing the program as a stand alone, executable code, (c) bypassing the IFG4 subprogram when field data are input into the program, and (d) incorporating bed material gradations into the evaluation process. The modified RCHARC program was executed producing bivariate plots and Canberra metric coefficients similar to those produced in the Beta test. The removal of the empty depth-velocity pairs and inclusion of the bed gradation comparison appeared to magnify the similarity between comparison reaches.

The RCHARC methodology was determined to be a reasonable approach to habitat rehabilitation that may be used in conjunction with a traditional flood channel design and evaluation. A procedure is presented for conducting a comprehensive flood control/habitat quality analysis.